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ANPC National Office

GPO Box 1777
Canberra, ACT 2601, Australia

T (02) 6250 9509 | **F** (02) 6250 9599
E anpc@anpc.asn.au
W www.anpc.asn.au

ANPC Staff

Martin Driver, Lucy Commander,
Jo Lynch

ANPC Volunteers

Robert Hawes

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New Zealand Plant Conservation Network

President Sarah Beadel
Secretary Rewi Elliot

PO Box 2199, Wellington, New Zealand

E info@nzpcn.org.nz
W www.nzpcn.org.nz

Front cover: *Grevillea scapigera* translocation. 2017 seed harvest (7th harvest after 14 years in the ground). Kings Park and Botanic Garden Volunteer Master Gardener Len Burton and Bob Dixon former Manager Biodiversity and Extensions. Photo: Robin Campbell

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Editor
Heidi Zimmer

Associate Editors
Nathan Emery and Selga Harrington

Editorial Team
Michelle Haby, Lucy Commander,
Bob Makinson, Cath Offord, Kylie Moritz
and Jo Lynch

Layout & Graphic Design
Siobhan Duffy

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Contributing to *Australasian Plant Conservation*

Australasian Plant Conservation is a forum for information exchange for all those involved in plant conservation: please use it to share your work with others. Articles, information snippets, details of new publications or research and diary dates are welcome. General articles on any plant conservation issue are most welcome.

The deadline for the **March to May 2019 issue is 15 February 2019.** The special theme for the issue is **Papers from the 12th Australasian Plant Conservation Conference.** If you are intending to submit an article or wish to discuss possibilities, please email the editor, Heidi Zimmer: **editor@anpc.asn.au**.

Authors are encouraged to submit images with articles or information. Please submit images in electronic format, resolution needs to be at least 300 dpi, at least the size that they are to be published, in tif, jpg or gif format. Guidelines for authors and an article template are at: **http://www.anpc.asn.au/apc**.

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From the editors

HEIDI ZIMMER, SELGA HARRINGTON AND NATHAN EMERY

Welcome to the next installment in our series on threatened plant translocation. We begin this issue with a report from our President, Linda Broadhurst, who gives an overview of the ANPC's activities during 2018.

Then we jump into some applied ecology with an article on the benefits of mycorrhizal fungi in restoration, by Lena Neuenkamp and others. The first translocation case study in this issue focuses on *Hibbertia spanantha*. Translocating the Critically Endangered *H. spanantha* has proven difficult after all plants from an initial small-scale planting trial died. However, Chantelle Doyle and her co-authors explain that observations during monitoring events provided information that will benefit subsequent translocations of the species. This case study is also a timely reminder that record-keeping during the propagation stage can provide key information for producing hardy plants for translocation.

The next translocation case study is on *Wollemia nobilis*, describing an experimental translocation undertaken (by a team including the editor) in 2012, to assess variation in growth and survival according to microsite light availability. We found that survival was greater where there was more light, in large part due to *Botreyosphareia* sp. (fungus) induced mortality in darker microsites. Initial condition of the Wollemi pines, which varied according to supplier, also had a significant impact on growth and survival. This is followed by the story of *Symonanthus bancroftii*, told by Eric Bunn and Shane Turner. Thought to be extinct, a single (male) plant of *S. bancroftii* was discovered in 1997. A female plant was found in 1998, and after some challenges, methods for propagation were determined. *Symonanthus bancroftii* now exists in two translocation sites with around 80 plants.

Carole Elliott and co-authors present some early results from translocation of *Tetratheca erubescens* associated with a mining offset. The translocation has been designed to compare performance of tubestock and direct seeding. Last but not least we have the case study of *Grevillea scapigera* by Bob Dixon and Siegy Krauss. *Grevillea scapigera* was presumed extinct in 1986, and after rediscovery in 1989 was subject to translocation 25 years ago. There have been numerous learnings from this project, not least about how to manage problems with genetic diversity.

In our regular features, news from the Australian Seed Bank Partnership highlights a fabulous project which aims to restore remnants of Cumberland Plains Woodland in Western Sydney. The ANPC workshop report is on the native plant identification and use workshop held in September in Broken Hill. We also have a report from Adam Miller on the genetic results from the (first) Bringing Back the Banksias project. Our member profile is of Dave Coates, who has made – and continues to make – a prolific contribution to native plant conservation in Australia. We round out with book reviews, news and our research round up.

Thank you to all our contributors in 2018, and to our ANPC membership for their ongoing support.

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President's Report

To the Annual General meeting, 12 November 2018

LINDA BROADHURST

ANPC President, Australian Network for Plant Conservation Inc.
Email: anpc@anpc.asn.au

This is the 27th year of the ANPC and it is pleasing to see that we continue to maintain our role as Australia's key plant conservation organisation.

The ANPC has again been involved in submissions to government either through participation in workshops or commenting on proposed legislative changes or guidelines. For example, the ANPC undertook joint submissions with the Invasive Species Council on the recent Senate Inquiry into the impacts of feral deer, pigs and goats in Australia and the Inspector General of Biosecurity's Review of environmental biosecurity risk management in Australia. The ANPC has also been an active participant in the environmental biosecurity review through participation at several meetings and roundtables by Bob Makinson and myself. In June 2018 the Office of Environmental Biosecurity was announced and sits within the Department of Agriculture and Water Resources.

The ANPC continues to maintain its strong involvement in promoting awareness of the Myrtle Rust threat to Australia's biota, and advocating for action. This has been a focus of activity by Bob Makinson since 2010. We are the only organisation, government or non-government, to have rolled out a national awareness program of workshops, collaborating with many agencies. In a non-ANPC capacity, and drawing on a network of specialists in which ANPC has played a central coordinating role, Bob recently completed a review of the environmental impacts of Myrtle Rust and a draft action plan for addressing it.

The Myrtle Rust case exemplifies the growing threat to our native biota from exotic plant pathogens. A recent Senate Inquiry, and two major Commonwealth reports, are slowly influencing Australia's biosecurity system towards an increased and long-overdue focus on environmental biosecurity. ANPC is among the few plant-oriented NGOs to have been closely engaged in this process, and it needs to become one of our core areas of advocacy. At present our 'workforce' in this area is very small – members motivated to become involved in it should contact us.

Linda Broadhurst. Photo: Nathan Emery

The Australian community continues to demonstrate strong interest and support for plant conservation. To meet these expectations the ANPC is playing a key role in facilitating and communicating plant conservation initiatives and information across Australia. This is reflected in the ongoing participation of land managers, government departments, industry, the volunteer conservation movement and the broader community in ANPC workshops and conferences as well as the requests we receive from other organisations and government agencies to participate in and comment on various flora conservation initiatives. This year we also collaborated with the Society for Ecological Restoration Australasia (SERA) on the 2018 Albert Morris Award for an outstanding Ecological Restoration Project. The Award was presented to the Murray Riverina Travelling Stock Reserves project at the Gala Dinner at SERA's conference in September.

While I continue to be greatly impressed by the dedication and breadth of knowledge of ANPC members, we still face many significant challenges. We need to ensure that we continue to effectively promote the inherent value and cultural significance of our unique and wonderful flora to the broader Australian community and remain true to our core business of facilitating Australian plant conservation, threatened species recovery, ecological restoration and remnant vegetation management.

2018 ANPC Conference (APCC12)

The ANPC's flagship event is the biannual Australasian Plant Conservation Conference (APCC) and our 12th conference was held in Canberra in 11–15th November 2018.

This conference brought together a diverse range of participants including botanists, geneticists, ecologists, practitioners, land managers, and on-ground plant conservation managers from around Australia to review and highlight plant conservation achievements and challenges. The theme for the conference was '*Moving House – A new age for plant translocation and restoration*'. Together we explored recent advances and latest scientific findings for successful threatened plant translocations and restoration across Australia. Species translocations have been an important conservation approach for more than two decades to save threatened species from extinction. With no foreseeable reduction in threats from climate change, urban and agricultural expansion and intensification, and invasive pests and diseases, plant translocations and restoration will continue to be an important component of plant conservation into the future.

Environmental change including through climate-induced events such as drought and fire as well as ongoing habitat loss and degradation continue to challenge our plant species. Halting and reversing species decline is a significant global challenge for the 21st century with the next few decades being pivotal to success. With Australia being home to more than 21,000 known plant species the conservation challenges are large but not insurmountable. New genomic approaches are beginning to unlock the genetic past of our plants offering opportunities to understand their capacity to respond to change in the future. The use of remote sensing and drone technology continues to expand the ecological frontier allowing us to better understand our ecological systems and processes. Artificial intelligence and machine learning applications are also growing rapidly and provide considerable promise in better species management such as the remote detection and identification of species in real time. These new technologies will not, however, replace the passion for our flora which is essential if we are to ensure that we leave a vibrant floral legacy for future Australia's to love and enjoy as much as we do.

I would like to thank all the conference sponsors and the conference organising committee: Josh McGregor, Damien Wrigley, David Coates, Lucy Commander, Chantelle Doyle, Nicki Taws, Jasmyn Lynch, Jo Lynch and Martin Driver for their huge effort in helping me coordinate the conference. Particular mentions go to Jo Lynch, Robert Hawes and Chris Ikin in the ANPC office as well as the other ANPC volunteers, and Josh McGregor from CANBR who all worked tirelessly to ensure that the conference ran smoothly.

Workshops, projects and outreach

One of our major projects in the last year as been to review and update the ANPC Translocation Guidelines in association with the National Environmental Science Programme's Threatened Species Recovery (TSR) Hub. The Steering Committee included Bob Makinson, Dave Coates, Cathy Offord, Maria Matthes and myself with the Project Manager being Dr Lucy Commander. Through Lucy's excellent guidance and oversight the third edition of the ANPC's *Guidelines for the Translocation of Threatened Plants in Australia* was launched by the Threatened Species Commissioner Dr Sally Box on 11th November 2018 at the ANPC Conference Welcome Reception. Lucy's dedication to this project has been immense and she has consulted with more than 30 experts from across Australia to ensure that the Guidelines are underpinned by the latest scientific findings. There are also 23 new case studies with colour photographs illustrating translocation techniques with many of these case studies also being published in the APC. This edition of the Guidelines will be essential reading for all those involved in translocation projects both in Australia and elsewhere. Many thanks go to Lucy, Dave, Cathy, Bob and Maria for the successful completion of this project as well as to the authors and experts who willingly gave their time to this project.

ANPC Project Manager, Martin Driver has continued to deliver workshops despite taking extended leave and restricted opportunities this year due to the effects of the current drought. A '*Plant Identification and Use*' Workshop was held at Mutawintji National Park with Western Broken Hill Junior Landcare in September, supported by the NSW Environmental Trust and Western Local Land Services. Meetings and site inspections were held in August with the Hunter Joint Organisation of Councils regarding the NSW Environmental Trust funded Hunter Corridors Project and a Direct Seeding Workshop was held there in late November. More of these workshops are planned for 2019. These workshops have been a great opportunity to directly provide private land managers with information on how to improve biodiversity management on their properties. Martin has also participated in the multi-agency '*Wild Orchids*' project meetings in the Murray catchment and provided project support.

Funding was received for Stage 2 of the Bringing Back the Banksias project from the Norman Wettenhall Foundation for continuation of the ANPC's networking and communications role between researchers and practitioners. It has enabled further *Banksia marginata* collections to be taken from relict populations or trees from Kangaroo Island, North East Victoria, Southern NSW, Upper Murrumbidgee and New England for analysis in conjunction with The Royal Botanic Gardens Sydney '*Restore and Renew*' project. Genetic analysis is still to be completed and cross referenced with sub-samples from the previously completed Victorian projects.

Once analysis is completed, a workshop to communicate findings and implications is planned for 2019.

In late 2016 Australian seed collectors, growers/sellers/suppliers, purchasers/distributors and other interested parties participated in an ANPC survey on the status of the Australian native seed industry. The project team was Nola Hancock (Department of Biological Sciences, Macquarie University), Paul Gibson-Roy (Greening Australia), Martin Driver (ANPC) and myself. The survey aimed to gauge the structure and capacity of the native seed sector to meet current and future demand, and to gather feedback on issues being experienced within the sector. The initial survey results were disseminated at the Australian Native Seed Industry Review workshop at the ANPC's 2016 conference in Melbourne. Following this event we received a large number of requests to re-open the survey and it was extended to April 2017. Survey results have been collated and interpreted over the last year with the final report to be launched in early 2019. Thanks to Nola, Paul and Martin for their efforts in helping to understand this critical part of plant restoration. The survey results presented at the 2016 workshop are available on the ANPC website.

Over the past 12 months, the ANPC has collaborated with the Orchid Conservation Program at the Royal Botanic Gardens Victoria (RBGV) on two projects. The '*Saving the Threatened Audas Spider-orchid (*Caladenia audasii*) from extinction'* project funded by DELWP in 2017 has resulted in seed collection and propagation of seedlings, hand pollination of wild plants, pollinator baiting and the construction of an exclusion fence to protect newly discovered plants from grazing kangaroos and rabbits. This project is due to finish in June 2020 with the re-introduction of 200 plants. This year DELWP also funded a similar project '*Saving the Brilliant Sun Orchid (*Thelymitra mackibbinii*) from extinction*'. This project will undertake pollinator surveys as well as the construction of two exclusion fences and signage. Community volunteers will undertake surveys and reintroductions of 600 propagated seedlings.

Our outreach efforts continue to expand through social media with the regular sharing of news and events in plant conservation via Twitter, Facebook, and LinkedIn with Instagram recently added. Our monthly email newsletter *ANPC News* continues to reach at least 630 subscribers. A new look ANPC website has been developed and we plan to launch this early in 2019 once content from the existing website has been copied across and the Eway payment gateway has been established.

Our bulletin, *Australasian Plant Conservation*, has continued to publish high-quality articles relevant to a broad range of plant conservation practitioners and managers, under the editorship this year of Heidi Zimmer and more recently our new assistant editors Nathan Emery and Selga Harrington. We sincerely thank Heidi, Nathan and Selga for their efforts over the past year in ensuring that APC continues to be a quality and well-respected publication communicating Australasian plant conservation issues. And I'd also like to thank Paul Adam for his oversight and guidance during our transition to a new editor and Siobhan Duffy for her design work on each edition.

Staffing

Many thanks to our Business Manager Jo Lynch, who continues to work well beyond the call of duty for the ANPC. Her dedication, advice and support make my role and the work of the Committee much more effective, and ensures that the ANPC continues to function as a highly respected conservation organisation. Also sincere thanks to our office volunteers this year – Chris Ikin, Robert Hawes, Karen Khoo and Eleanor Gates-Stuart who have helped enormously with various tasks including graphic design, social media, ANPC News and financial processing. Carly Westbye resigned from her position as Office Administrator in March after five years and I thank Carly for her hard work during that time including her willingness to undertake additional tasks including many graphic design projects and assisting with the editing of APC.

I am grateful to Committee members for their tremendous support over the year. All of the Committee members have significant commitments outside the ANPC and it is often challenging to devote the time required to be active committee members. The involvement in the committee by all members is a clear demonstration of their dedication to the ANPC and its goals in improving plant conservation. I would like to thank ANPC Committee member Michelle Haby who is leaving the committee this year and I sincerely thank her for her time and support over the last four years.

I would especially like to thank Chris Ikin who took over as Treasurer last year. His experience and assistance in this role, as well as additional volunteering in the office, has been a huge asset to the ANPC over the last year. This includes many hours helping to finalise the implementation of Xero in the office and fine tuning the auditing process and merchant banking facilities. Bob Makinson has been a tower of support this year, especially during fund raising activities and his long term dedication to ANPC and wise counsel have been highly valued.

Funding

As you will be aware 2018 was a financially challenging year for us but thanks to the dedication of the committee and the members we were able to exceed our fundraising target of $20,000 by 30 June 2018. This was a tremendous result and highlights the dedication of our members to ensuring that the ANPC continues to advocate and educate for Australasian plant conservation. Our financial situation was reported on in detail separately at the AGM but some of our keys sources of income this year have included:

- Threatened Species Recovery Hub for the Review of the ANPC's Translocation Guidelines.
- NSW Environmental Trust's Lead Environmental Community Groups grant for website development, social media and Plant ID workshops.
- Normal Wettenhall Foundation biodiversity conservation grant for Stage 2 of the *Bring Back the Banksias Project* – coordination, communication and workshop.
- Western Local Land Services for a Plant ID workshop.
- Hunter Joint Organisation of Councils for a Direct Seeding Workshop.
- Biodiversity On-ground Action 2018 - Community & Volunteer Action Grant (Victoria) for $44,440.20 for 'Saving the Brilliant Sun Orchid (*Thelymitra mackibbinii*) from extinction'.
- SA Murray Darling Basin NRM Volunteer Small Grants with Eastern Hills and Murray Plains Catchment Group to contribute to SA Threatened Plants Translocation Workshop.
- Many donations as a result of our emergency fundraising drive earlier this year.

I would like to thank Jo Lynch and Martin Driver for their efforts in seeking projects and grants – while not every application is successful, we rely heavily on their efforts to continue to seek funding to support our key activities.

The coming year

Many projects are already in the planning stage for the coming year. These include:

- Initial planning for the 13th Australasian Plant Conservation Conference in 2020.
- Launch of the National Seed Supply Survey.
- Promulgating the new Translocation Guidelines including through Plant Translocation workshops in South Australia and Western Australia and seeking additional funding for further translocation workshops.
- Seeking funding to revise the ANPC's Germplasm Guidelines.
- Completing Stage 2 of the Bring Back the Banksias project.
- Undertaking the two orchid projects with RBGV.
- Coordinating more seed collection and plant ID workshops.
- Finalising the new website.
- Investigating the potential for an ANPC Forum in 2019.

I have thoroughly enjoyed my time as President over the last 3 years. It has been a pleasure and a privilege to work with all of you and for an organisation that does so much for plant conservation in Australia. I see an ongoing and important future for the ANPC as it continues to play a key role in plant conservation across Australia and the region more broadly.

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Mycorrhizal fungi benefit ecosystem restoration, but how much depends on plant functional type, restoration context and time

LENA NEUENKAMP[1*], SUZANNE M. PROBER[2], JODI N. PRICE[3,4], MARTIN ZOBEL[1], RACHEL J. STANDISH[4,5]

[1] University of Tartu, Estonia
[2] CSIRO Land and Water, Australia
[3] Institute of Land, Water and Society, Charles Sturt University, Australia
[4] School of Biological Sciences, The University of Western Australia, Crawley, Australia
[5] School of Veterinary and Life Sciences, Murdoch University, Australia
*Corresponding author: Lena Neuenkamp; lena.neuenkamp@ut.ee; tel: +372 56879109

Mycorrhizal inoculation can enhance outcomes of ecological restoration: But how much and when is it most beneficial?

Human activities have degraded nearly two-thirds of all ecosystems (Millennium Ecosystem Assessment 2005) with significant consequences for biodiversity and ecosystem function (TEEB 2010). In many cases, degraded ecosystems need ecological restoration to recover biodiversity and ecosystem function (SER, 2004), but achieving this can take decades or may ultimately fail due to abiotic (*e.g*. eutrophication, acidification) and biotic constraints (*e.g*. competition, unfavourable soil community composition) (Suding *et al.* 2004; Grman *et al.* 2015). Mycorrhizal inoculation can enhance outcomes of ecological restoration, because plants benefit from hosting these obligate symbionts, but the circumstances in which addition of mycorrhizal fungi is beneficial to restoration outcomes is poorly known (Kardol and Wardle 2010).

We searched the literature for field studies of mycorrhizal inoculation to identify conditions in which adding mycorrhizal fungi enhances the success of ecological restoration. We searched the ISI Web of Science database (1900–2016) using the key word string mycorrhiza* AND (restoration OR reclamation OR rehabilitation), and identified 758 potentially suitable studies. We read the abstracts of all 758 studies and selected those ones that experimentally added mycorrhizal inoculum in the context of ecological restoration under field conditions and inoculated plants to a non-mycorrhizal control contrast. We only included studies that sterilised control soils with gamma-irradiation or autoclaving, but excluded those using fungicides, since the latter can bias results in control plots by not eliminating all fungi but shifting fungal community composition. Further, we included only studies that provided treatment means, a measure of variance (standard deviation or standard error) and sample size for plant growth (biomass or height) or species richness. These criteria reduced the number of studies to 34 studies. We assessed plant responses to mycorrhizal inoculation from 34 studies, focussing on plant growth (biomass) and plant species richness, and their dependence on six explanatory factors: plant identity (plant functional group), soil conditions (soil pH, concentrations of total nitrogen N and plant-available phosphorus P), disturbance history (severity of soil disturbance) and fungal identity (single species to whole soil inoculum). We also assessed the development of inoculation effects over time. From each study, we extracted information on treatment means and variation of plant biomass, height and species richness as well as on the explanatory factors. Plant response to inoculation was calculated as the natural logarithm of the response ratio as the ($\ln(R) = \ln$ (inoculated/non-inoculated)) that is greater than zero for a positive effect of inoculation on plant biomass, height or species richness and vice versa for a negative inoculation effect. We used random mixed-effect models to estimate the size and significance of mycorrhizal inoculation in plant biomass, height and species richness, as well as their response to the explanatory factors.

On average, mycorrhizal inoculation promoted plant growth by 170% and plant richness by 30%.

Our analysis revealed that inoculation with mycorrhizal fungi enhanced plant growth in restored grasslands, shrublands and woodlands ranging from semi-arid to mesic sites around the world (Neuenkamp *et al.* 2018). The effect was substantial (increasing biomass by an average of 170% across the 26 studies that measured biomass) (Table 1) and tended to increase over time. A small subset of studies also examined plant species richness and similarity of restored species composition to reference communities. Mycorrhizal inoculation increased species richness of restored plant communities by an average of 30% in these studies (Table 1), and increased the similarity of restored communities to reference communities.

Strength of inoculation effects on plant growth was strongly context dependent. Inoculation was most beneficial to plants with greater nutrient demand (woody nitrogen-fixers), plants with inefficient nutrient-uptake (C4-grasses) and plants growing on severely disturbed or nutrient-poor soils (low in total nitrogen or plant-available phosphorus). Plant growth responses tended to be greater for whole-soil inocula than less diverse inocula, but this effect was not significant (Table 1).

Mycorrhizal inoculation is most beneficial for rapid establishment of ground cover with C4 grasses and initiating vegetation recovery with N-fixing trees in nutrient poor, degraded sites.

Overall, we conclude that mycorrhizal inoculation can promote plant growth and plant species richness in field conditions, offering a promising opportunity to improve the outcomes of ecological restoration projects. Although most studies showed some benefit of inoculation, greatest benefits would be expected for:

1. Projects aiming for rapid establishment of ground cover in highly degraded sites using C-4 grasses or where nitrogen-fixing woody species are planted to initiate ecological restoration (*e.g*., Daws *et al*. 2015, Figure 1).
2. Projects involving P-limited or highly degraded soils (*e.g*., mine sites and areas degraded by soil erosion, see Figure 2).

Our conclusion that mycorrhizal inoculation can enhance plant species richness is encouraging, but is based on few studies. We suggest further research should focus on the benefits of using mycorrhizal inoculation to restore whole plant communities, including measures of plant diversity and composition over a broad range of ecosystem types and environmental conditions.

References

Daws, M.I., Standish, R.J., Koch, J.M., Morald, T.K., Tibbett, M. and Hobbs, R.J. (2015). Phosphorus fertilisation and large legume species affect jarrah forest restoration after bauxite mining. *Forest Ecology and Management* 354: 10-17.

Grman, E., Bassett, T., Zirbel, C.R. and Brudvig, L.A. (2015). Dispersal and establishment filters influence the assembly of restored prairie plant communities. *Restoration Ecology* 23: 892–899.

Kardol, P. and Wardle D.A. (2010). How understanding aboveground-belowground linkages can assist restoration ecology. *Trends in Ecology and Evolution* 25: 670–679.

Millennium Ecosystem Assessment (2005). *Ecosystems and human well-being: current state and trends*. Island Press, Washington, US.

Neuenkamp L., Prober, S.N., Price, J.N., Zobel, M., and Standish, R.J. (2018). Benefits of mycorrhizal inoculation to ecological restoration depends on plant functional type, restoration context and time. *Fungal Ecology* (in press).

Society for Ecological Restoration Science & Policy Working Group (2004). *The SER Primer on Ecological Restoration*. Available at: www.ser.org.

Suding, K.N., Gross, K.L. and Houseman, G.R. (2004). Alternative states and positive feedbacks in restoration ecology. *Trends in Ecology and Evolution* 19: 46-53.

TEEB (2010). *The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB*. Available at: www.teebweb.org.

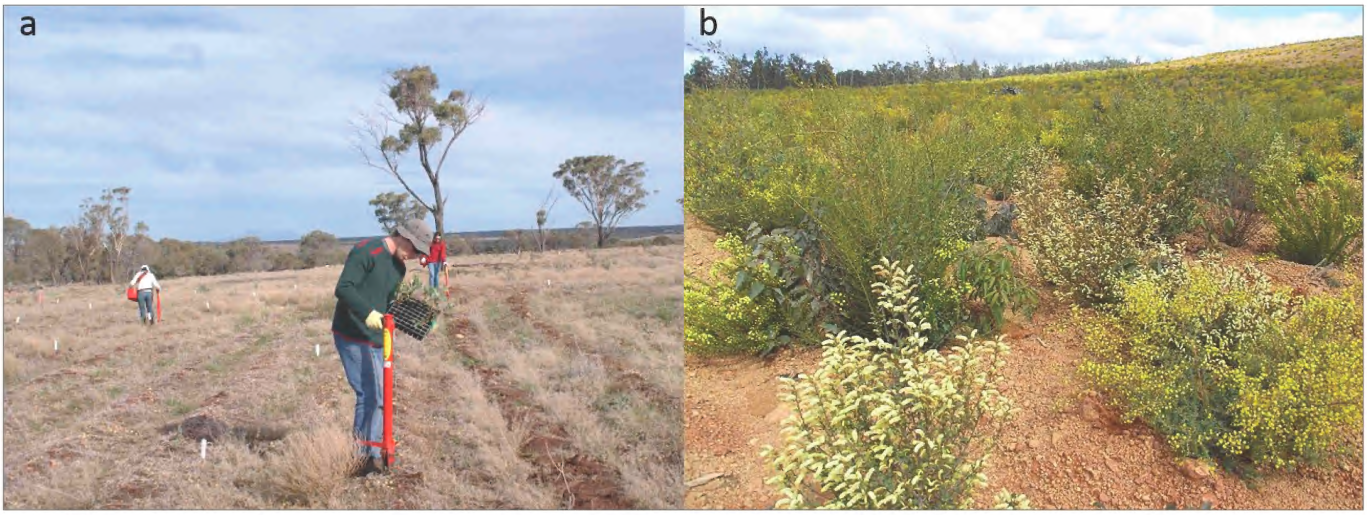


Figure 1. Restoration projects in south-western Australia: a) old-field restoration; planting eucalypt and acacia seedlings to restore native Yate woodland and; b) jarrah forest restoration after bauxite mining; 15 months after landscaping, soil ripping, topsoil application and seeding (with acacias flowering in yellow). Mycorrhizal inoculation could potentially benefit the growth and survival of the restored native plants such as the eucalypts and N-fixing acacia species. Project leader Rachel Standish. Photos: Rachel Standish (a) and John Koch (b).

Response/Factor	Benefit	P value
Plant richness	⊕ 25 ± 5%	<0.001
Plant biomass	⊕ 70 ± 15%	<0.001
Plant functional group	N-fixing C4 > non N-fixing C3	<0.001
Soil disturbance	disturbed > undisturbed	<0.001*
Plant available phosphorus (P) in the soil	low P soils > high P soils	0.005
Total soil nitrogen (N)	low N soils > high N soils	0.028
Inoculum type	●●○ species poor fungal mixes < ●●●○●○●○● whole soil fungal community	<0.001*

Table 1. Summary table showing the variation in the effect of mycorrhizal inoculation on plant biomass and plant richness, in relation to different explanatory variables. Results marked with * were significant when inoculation effects were assessed over time (*i.e.*, 3 years compared with assessment 2-3 month after restoration; for details see Neuenkamp *et al.* 2018).

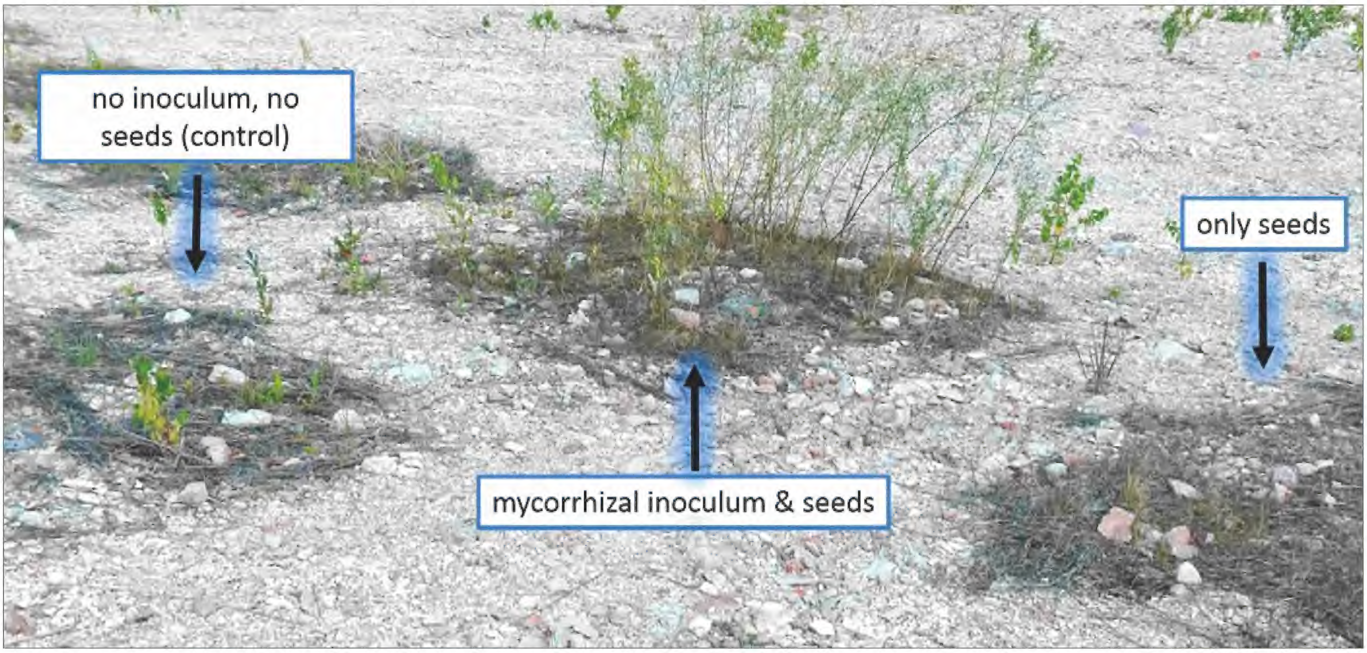


Figure 2. Vegetation recovery one year after a restoration trial in a limestone quarry in NE Estonia (Europe) testing the effect of different restoration means: only seeds of native grassland species, native seeds and whole-soil mycorrhizal inoculum from reference grassland sites or neither seeds nor inoculum. The mycorrhizal + seed treatment led to the best vegetation recovery. Project leaders Maarja Öpik, Tanel Vahter. Photo: Tanel Vahter

Threatened plant translocation case study:

Hibbertia spanantha Toelken & A.F.Rob (Julian's Hibbertia), Dilleniaceae

CHANTELLE DOYLE[1*], BELINDA PELLOW[1], MARK HOOD[2], ROSS RAPMUND[2], MARK VILER[3]

[1] AMBS Ecology and Heritage Pty Ltd
[2] Hornsby Shire Council
[3] The Australian Botanic Garden Mount Annan
*Corresponding author: chantelle@ambs.com.au

The species

- Perennial long lived erect to prostrate subshrub.
- Endemic to the Sydney basin.
- First located in 2007 in Turramurra, Sydney.
- A second population discovered in Spring 2013.
- Gazetted in 2015.
- Now known from only 3 disparate locations.

Threatening processes

- Habitat loss and fragmentation.
- Urbanisation.
- Altered fire regimes.
- Genetic depression.
- Lack of reproduction.
- Invasive species.

Deciding to translocate

Hibbertia spanantha was discovered in 2007 from one discrete location in the suburb of Turramurra, Sydney, and was originally known as *Hibbertia* sp. Turramurra (A.F.Robinson s.n. NSW981514). It was formally described as *Hibbertia spanantha* in 2015 (Toelken and Robinson 2015) and has been listed as Critically Endangered under the New South Wales *Biodiversity Conservation Act 2016* and the *Environmental Protection and Biodiversity Act 1999*. This listing was primarily based on the species' limited distribution and low number of mature individuals (NSW Scientific Committee 2015; Threatened Species Scientific Committee, 2016). At the time of implementing the translocation program, only two other populations had been located. One of these comprised of six individuals and was confined within a fragmented bushland reserve located in the Hornsby Local Government Area (LGA). A development within the vicinity of the reserve posed a potential risk, given the species' limited population size. Additionally, no occurrences of successful reproduction had been recorded (*i.e.*, no seeds or juvenile plants had been observed). It was then decided to augment the population to provide insurance against the possibility of unintentional damage caused by the development.

Aim of the translocation

Although the nearby development posed no immediate threat to the population, the proximity of works and lack of signs of reproduction, meant the population may have been in danger of accidental damage leading to, at worst, local extinction. The translocation program aimed to provide short- to medium-term insurance for the local population, in the event of damage from the adjacent development. Initial plans to augment the existing population through direct seeding were quickly stymied when no viable seed could be located. Instead, the program sought to introduce additional plants propagated from cuttings. The cuttings were to be collected from the parents in the reserve and used to propagate individuals for planting in similar habitat near the parents.

Translocation working group and key stakeholders

- AMBS Ecology and Heritage Pty Ltd.
- Hornsby Shire Council.
- The Australian Botanic Garden Mount Annan.

Biology and ecology

- Insect pollination.
- Seeds probably gravity dispersed.
- Possibly fire dependent germination.
- Generally flowers October-November, although plants have been observed to produce flowers throughout the year (OEH 2017).
- Grows in tall open forest vegetation associated with sandy to light clays of Coastal Enriched Sandstone Dry Forest and or Coastal Shale Sandstone Forest (OEH 2013 in Toelken and Robinson 2015) and Sydney Turpentine Ironbark Forest (OEH 2013). These communities occur within the broader

vegetation classes of Sydney Coastal Dry Sclerophyll Forests and Northern Hinterland Wet Sclerophyll Forests (Keith 2004).

Site selection

Propagated plants were replanted near the parent plants, in areas determined by field surveys as Sydney Turpentine Ironbark forest. Site inspections further refined the planting locations based on aspect, sun exposure/shade and litter depth relative to the parent plants.

Translocation proposal

The proposal for propagation and population augmentation was embedded in the project development Environmental Management Plan and required as a project condition of consent. The proposal was also reviewed by Hornsby Shire Council.

Pre-translocation preparation, design, implementation and ongoing maintenance

The Australian Botanic Garden Mount Annan (ABGMA) was commissioned to collect and propagate cuttings from each parent *Hibbertia*. Cuttings were struck from a combination of 'soft-tip' and 'semi-hard wood' material, using a two-staged hormone treatment developed by ABGMA nursery. A total of 27 cuttings were collected from three individual specimens (clonal), of which a total of 18 cuttings successfully struck. Of the 11 cuttings that survived, eight were supplied for translocation and 3 were retained by ABGMA as part of *ex situ* conservation. The retained cuttings were used for a second iteration of propagation, however only one of the accessions produced surviving cuttings. The eight *Hibbertia spanantha* cuttings from the first propagation represented three accessions (individual specimens).

Planting occurred in pre-selected locations in autumn 2015, a period which corresponds with a slowing in the active growth of many native plant species. In addition, autumn planting reduces the risk of transplant shock by providing a period of establishment before summer heat stress. The cuttings were collected from the ABGMA nursery one day prior to planting and were visibly robust, with a higher leaf biomass than the parent plants. Two of the cuttings had developed a stunted appearance quite dissimilar to that of the parent plants. The propagated *Hibbertia* plants had also flowered the previous season in the nursery but did not produce fruit.

Prior to planting, each cutting was assigned a recording number and baseline data was collected at each location. This included descriptive information (date, coordinates, tag number, accession number and location description); abiotic factors (soil texture and colour, percent bare ground, leaf litter depth (mm), depth to parent material (mm) and plant health (total height (mm), evidence of disease/stress, evidence of flowering/fruiting, growth form). In addition, soil cores were collected from each hole prior to planting using a single cylinder, hammer driver and 4.86 cm diameter coring tube. Samples were collected to 10 cm depth. Samples were stored in a sealed plastic zip lock bag, with relevant site codes, and refrigerated until analysis.

At the time of planting the soil moisture levels were high and the soil was wet to the touch; but no soil moisture readings were collected. Planting sites were physically tagged and coordinates were recorded. Planting holes were deep enough to only cover the root ball and no deep stem planting was conducted. Approximately 300–500 ml of water was placed in the bottom of each hole prior to planting, with an additional 500 ml used to water each individual immediately after planting. At the time of planting the root structure of the *Hibbertia* was noted as a fine network of delicate roots and no discernible vertical tap root. Plants were watered the day after planting with 300-500 ml of water, and then every 2 days for one-week post planting.

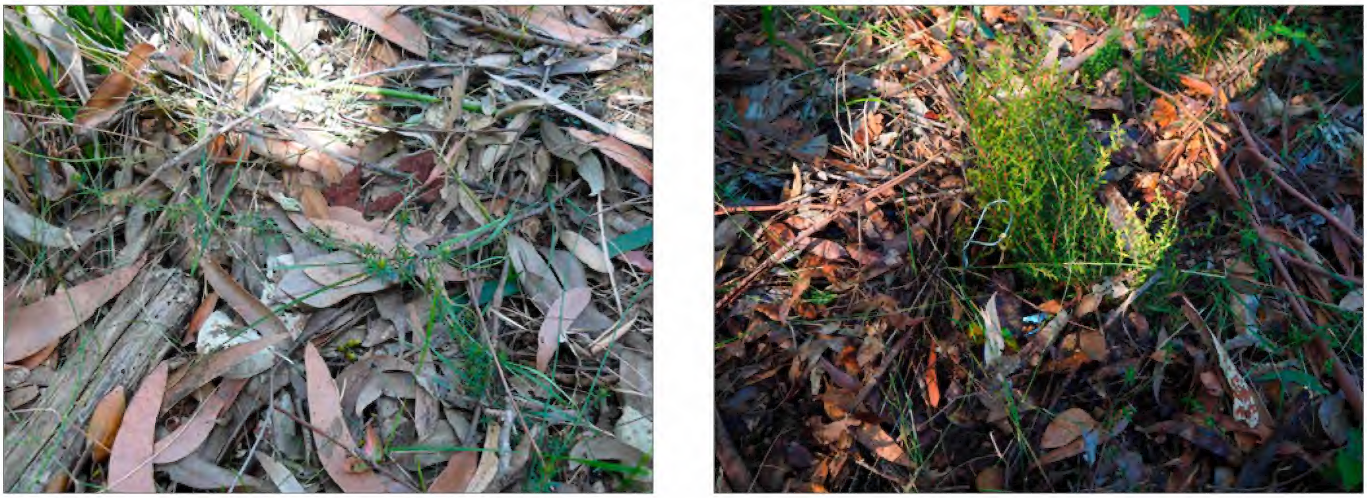


Figure 1. Parent *Hibbertia spanantha* (left) has a much lower leaf biomass that the majority of planted individuals (right) (April 2015). Photo: Chantelle Doyle

After this time, watering occurred weekly for one month in accompaniment to monitoring of the plant health. Regular watering ceased in July 2015. However, after a long dry spell over November and December, translocated *Hibbertia* plants were watered. At the time of watering the soil was still damp to the touch but drier than at the time of planting.

Monitoring of plants occurred for one-year post planting (concluding June 2016). Throughout autumn and winter 2015, all plants were healthy and the natural soil condition moist due to regular rainfall.

Translocated *Hibbertia* plants began to produce buds in September and October, but four of the planted individuals died whilst in bud or with partially opened flowers. The three surviving *Hibbertia* were much smaller in stature (Figure 2), two being of a morphologically 'stunted' accession and the third dropping most of its leaves. One of the plants from the 'stunted' accession was reported as dead in April 2016 and a second plant was reported as dead in June 2016. At the time of the final monitoring, only one *Hibbertia* remained alive, albeit with only very sparse basal leaves remaining. This plant has since died.

Analysis of soils collected from both pots and planting sites showed the planting site soils had lower moisture content (%), pH, electrical conductivity and nitrogen and phosphorous levels (recorded as available P, ammonia, nitrate/nitrite) than pot soils. Percentage carbon was also recorded but varied considerably between samples.

Subsequent actions

Anecdotal observations suggested that soil nutrients and period of 'hardening off' may have a role in the survival of cuttings when planted back into their natural habitat. A second propagation and population augmentation trial is being conducted by AMBS and Hornsby Shire Council, with support of the NSW Office of Environment and Heritage (OEH) to test this possibility. Cuttings for this trial have been acquired from accessions retained by ABGMA after the original trial.

The second trial began in August 2017 with the aim to propagate 25 *Hibbertia spanantha* under five nutrient treatments (including using provenance soil), and the intent being to plant cuttings near the parent population after a standardised period of hardening off. Each of the planted individuals will be monitored for a minimum of two years post planting.

The trial is already yielding interesting results about propagation techniques and plant performance in a nursery environment

Outcomes

The original aim to augment the existing population of *Hibbertia spanantha* was not achieved, as all planted individuals have died. Observations during the first program have however provided insights into the behaviour of the plants which has posed further questions on potential for the propagation and translocation of this species. This has led to a second propagation and planting trial with cuttings planted in autumn 2018. This new trial aims to monitor the impact of growing medium, nutrient levels and hardening off on the survival of planted individuals. Lessons from the failed translocation and the new trial will be used to inform future propagation practice and hopefully improve long term survival success.

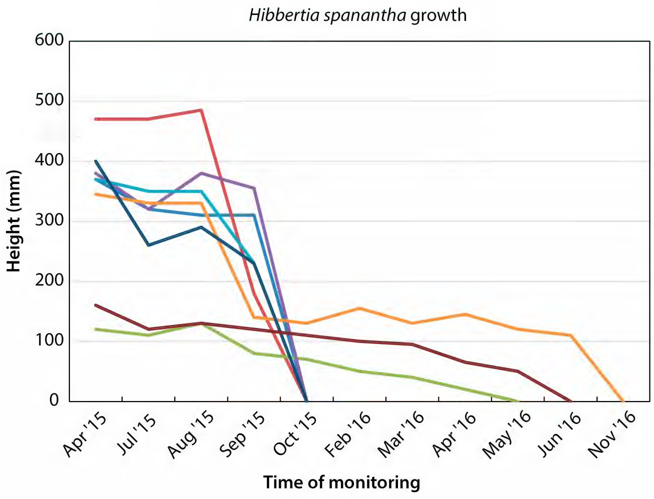


Figure 2. *Hibbertia spanantha* height (mm) of different individuals from planting to termination of monitoring in November 2016.

What we learned

- Propagation of cuttings using rooting hormone and standard potting media had high initial success. The species can produce struck cuttings from a variety of plant ages, *i.e.*, both tip material and woodier sections of plant tissue.
- *Hibbertia spanatha* propagation success can depend on the parent plant, collecting from a variety of individuals may be important for propagation success.
- Flowering occurs from September to November, but may also respond to positive environmental cues at other times of year (as indicated in the Threatened Species Profile (OEH 2017) and flowering in nursery environment).
- Plants with lower leaf biomass survived longer post planting. This may also reflect potting mix nutrient levels.
- The bulk of plant deaths coincided with flower production. It is uncertain if flower production was a factor contributing to plant senescence or occurred as a response to plant stress. Strategies to manage flowering the first year post-planting may increase survival (*e.g.* pruning, additional water).

References and further reading

Keith, D.A. (2004). *Ocean shores to desert dunes: the native vegetation of New South Wales and the A.C.T.* Department of Environment and Conservation, Hurstville.

OEH (2013). *The Native Vegetation of the Sydney Metropolitan Area (Version 2.0)*. Office of Environment and Heritage, Department of Premier and Cabinet, Sydney.

OEH (2017). *Julian's Hibbertia-profile.* Office of Environment and Heritage NSW Government, Sydney. Accessed 6th February 2018 Available from www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=20279

Scientific Committee (2015). Hibbertia sp. *Turramurra Final Determination NSW Threatened Species Scientific Committee*. Available from www.environment.nsw.gov.au/resources/threatenedspecies/determinations/FDHibbTurraCR.pdf

Threatened Species Scientific Committee (2016). *Conservation Advice* Hibbertia spanantha *Julian's hibbertia*. Department of the Environment and Energy, Canberrra.

Toelken, H.R. and Robinson, A.F. (2015). Notes on *Hibbertia* (Dilleniaceae) 11. *Hibbertia spanantha*, a new species from the central coast of New South Wales. *Journal of the Adelaide Botanic Gardens* 29: 11–14

Threatened plant translocation case study:

Wollemia nobilis (Wollemi Pine), Araucariaceae

HEIDI ZIMMER[1*], PATRICK BAKER[2], CATHERINE OFFORD[3], JESSICA RIGG[4], GREG BOURKE[5] AND TONY AULD[1]

[1] NSW Office of Environment and Heritage
[2] University of Melbourne
[3] The Australian Botanic Garden Mount Annan
[4] NSW Department of Primary Industries
[5] The Blue Mountains Botanic Garden Mount Tomah
*Corresponding author: heidi.zimmer@environment.nsw.gov.au

The species

The Wollemi Pine is a Critically Endangered conifer that is endemic to a single catchment in Wollemi National Park, NSW. Fewer than 100 mature Wollemi Pines remain in the wild. The Wollemi Pine is a high profile species since its discovery in 1994 by David Noble. It has attracted international media interest, and was dubbed a 'living fossil' because of its similarity to previously described fossil records (Chambers *et al.* 1998). The Wollemi Pine was the subject of the State of New South Wales' first Recovery Plan for a threatened species, which included *in situ* management and *ex situ* conservation actions. Another action was a campaign of 'cultivation for conservation' by the Royal Botanic Gardens and Domain Trust, with the first plants available for sale in 2005.

Biology and ecology

The trees occur in deep gullies within warm temperate rainforest. The tallest recorded Wollemi Pine is 42 m. Wollemi Pines are multi-stemmed and show little genetic variation among individuals (Greenfield *et al.* 2017), and recruitment from seed appears to be rare. Seed viability is typically around 10% (Offord *et al.* 1999) and the survival of germinants in the wild is around 35% (Zimmer *et al.* 2014a). Once seedlings establish, survival rates are higher, but growth rates remain low (Zimmer *et al.* 2014a).

There are around 200 seedlings and juvenile Wollemi Pines in the wild. It is likely that the creation of canopy gaps would increase Wollemi Pine recruitment, as many rainforest trees.

Threatening processes

The most significant threat to the Wollemi Pine is its limited geographic distribution. The risk of a single catastrophic event affecting all individuals is very likely.

Photo 1. Wollemi Pines in the wild. Photo: Heidi Zimmer

Fire is common within the surrounding landscape; however, Wollemi Pines are one of the few conifers with the capacity to resprout after fire (Zimmer *et al.* 2014b). Wollemi Pines are also affected by *Phytophthora* spp., which can cause mortality in seedlings (Bullock *et al.* 2000, Puno *et al.* 2015). Climate change also poses a further threat to Wollemi Pine due to its intolerance of high temperatures (Offord 2011) and drought (Zimmer *et al.* 2015). Wollemi Pines are also threatened by human-mediated disturbances, such as trampling, damaging trees, illegal collection and spreading *Phytophthtora* spp. It is for these reasons that the location of the wild Wollemi Pine population is kept secret.

Deciding to translocate

The Wollemi Pine Recovery Team discussed the need to translocate for several years, and the development of guidelines for Wollemi Pine translocation was recommended as part of the Wollemi Pine Recovery Plan (2007). Establishing new populations using translocation may reduce the risk of losing the entire wild population. However, the first requirement was to ensure that the species had adequate *ex situ* representation that could subsequently be used to produce material for translocations.

Aim of the translocation

The initial Wollemi Pine translocation had the broad aim of informing future translocations. There were several questions associated with the first translocation, including: (1) how does growth and survival of translocated Wollemi Pines vary along a light gradient? (2) how does light affect Wollemi Pine growth and survival, and does this vary with plant size? (Zimmer *et al.* 2016), and; (3) how do soil properties and soil microbial communities influence translocation success? (Rigg *et al.* 2017). We focused on the influence of light because of known positive effects on seedlings in the wild (Zimmer *et al.* 2014a) and in greenhouse experiments (Offord *et al.* 2014). We investigated the influence of plant size (stem length) as it is often positively correlated with growth and survival in translocation and because the available seedlings varied in size. Another potential benefit of the experimental translocation was, if successful, that it would become a viable *ex situ* population and reduce the risk of extinction of Wollemi Pines in the wild.

Translocation working group and key stakeholders

The translocation was a collaborative effort overseen by the Wollemi Pine Recovery Team, which includes members from the NSW Office of Environment and Heritage, Royal Botanic Gardens and Domain Trust, and the NSW National Parks and Wildlife Service. The translocation experiments were led by PhD students from the University of Melbourne and Western Sydney University.

Photo 2. Potted Wollemi pine clone at the Australian Botanic Garden Mount Annan. Photo: Heidi Zimmer

Photo 3. Translocated Wollemi Pine at recipient site. Photo: Heidi Zimmer

Site selection

The recipient site was selected to be similar to the wild site, in terms of soil (low pH), vegetation community (warm temperate rainforest), and climate. We selected an area of warm temperate rainforest on land managed by the Blue Mountains Botanic Garden Mount Tomah that provided long-term land tenure security, as well as ease of access for planting and monitoring, and the ability to limit public access.

Translocation proposal

A translocation proposal was developed following Vallee *et al.* (2004).

Pre-translocation preparation, design, implementation and ongoing maintenance

Prior to translocation, we conducted soil testing (focusing on *Phytophthora* spp. and soil pH), marked and georeferenced individual planting sites, and measured their light availability. We flagged 30 planting sites from the creek line (moister, darker) to the (drier, lighter) rainforest-woodland ecotone. We obtained 191 plants grown from cuttings from the Australian Botanic Garden Mont Annan (ABGMA) and a commercial supplier.

Planting was conducted in August 2012, which was before the Wollemi Pine's growing season (spring) and maximised volunteer and staff availability. All equipment was sterilised using 70% methylated spirits to minimise the potential for *Phytophthora* spp. infection. Wollemi Pines of varying sizes were planted in groups of 6 or 7 (in areas approximately 4 m x 4 m). Each plant was watered (around 5 L) and plant guards were placed around translocants in order to minimise Lyrebird disturbance. Initial stem length was measured. The plants were re-watered one month post-planting.

The translocated Wollemi Pine population was monitored intensively for the first 6 months after planting (four visits) and less intensively over the next 18 months (four visits). The plants have been subsequently monitored annually in February. Measures of survival, stem length, and number of branches were recorded. Additional notes on plant health and the presence of reproductive structures are also made.

Subsequent actions

Following on from the results of the experimental translocation, the Wollemi Pine Recovery Team is considering the potential to establish additional translocation sites in Wollemi National Park.

Outcomes

Around 82% of plants have survived since planting in 2012. In summer 2018, some of the larger plants (sourced from the ABGMA) developed male and female cones.

Our original aim was to determine the effect of light availability and plant size on translocated Wollemi Pine growth and survival. We found greater survival in sites with more light. This was largely due to high mortality in deeply shaded sites during the first winter post-translocation, associated with infection by the native pathogen *Botryosphaeria* sp. – an opportunistic fungus that attacks stressed plants. Growth and survival have been highly variable, with most of the variation attributed to the two plant suppliers, and differing plant condition at the time of planting. The effect of plant size has been difficult to disentangle. Of the ABGMA plants, larger individuals had high survival rates and grew fast, whereas small plants from the commercial supplier had high survival rates, but grew very little (Zimmer *et al.* 2016). In addition, we found that Wollemi Pines developed their own species-specific microbial communities after two years, and this unique community was linked to plant health and condition (Rigg *et al.* 2017).

What we learned

- Wollemi Pines can survive and grow at light levels much higher than at the wild site.
- Plant condition is key to survival. Acclimatise your plants before translocation in conditions as close as possible to that of the recipient site.
- Collaboration is the foundation of success. This work would not have been possible without the exceptional input from a diverse group of horticulturists, ecologists, soil scientists, land managers and science communicators.
- Unexpected things can happen – the mortality due to *Botryosphaeria* sp. in dark sites was unexpected.

References and further reading

Bullock, S., Summerell, B. A., and Gunn, L. V. (2000). Pathogens of the Wollemi Pine, *Wollemia nobilis*. *Australasian Plant Pathology* 29: 211-214.

Chambers, T. C., Drinnan, A. N., and McLoughlin, S. (1998). Some morphological features of Wollemi Pine (*Wollemia nobilis*: Araucariaceae) and their comparison to Cretaceous plant fossils. *International Journal of Plant Sciences*, 159: 160-171.

Greenfield, A., McPherson, H., Auld, T., Delaney, S., Offord, C. A., van der Merwe, M., Yap, J.S. and Rossetto, M. (2016). Whole-chloroplast analysis as an approach for fine-tuning the preservation of a highly charismatic but critically endangered species, *Wollemia nobilis* (Araucariaceae). *Australian Journal of Botany* 64: 654-658.

Offord, C. A., Porter, C. L., Meagher, P. F. and Errington, G. (1999). Sexual reproduction and early plant growth of the Wollemi Pine (*Wollemia nobilis*), a rare and threatened Australian conifer. *Annals of Botany* 84:1-9.

Offord, C. A. (2011). Pushed to the limit: consequences of climate change for the Araucariaceae: a relictual rain forest family. *Annals of Botany* 108: 347-357.

Offord, C., Meagher, P. and Zimmer, H. (2014). Growing up or growing out? How soil pH and light affect seedling growth of a relictual rainforest tree. *Annals of Botany Plants*. doi: 10.1093/aobpla/plu011

Puno, V. I., Laurence, M. H., Guest, D. I. and Liew, E. C. Y. (2015). Detection of *Phytophthora multivora* in the Wollemi Pine site and pathogenicity to *Wollemia nobilis*. *Australasian Plant Pathology* 44: 205-215.

Rigg, J., Offord, C., Zimmer, H., Andersen, I., Singh, B. and Powell, J. (2017). Conservation by translocation: establishment of Wollemi Pine and associated microbial communities in novel environments. *Plant and Soil* 411: 209-225.

Vallee, L., Hogbin, T., Monks, L., Makinson, B., Matthes, M. and Rosetto M (2004) *Guidelines for the translocation of threatened plants in Australia*. Australian Network for Plant Conservation, Canberra, Australia.

Zimmer, H., Offord, C., Auld, T. and Baker, P. (2016). Establishing a wild, *ex situ* population of a critically endangered shade-tolerant rainforest conifer: A translocation experiment. *PLOS One*, 11(7), e0157559.

Zimmer, H., Brodribb, T. and Baker, P. (2015). Drought avoidance and vulnerability in the Australian Araucariaceae. *Tree Physiology* 36: 218-228.

Zimmer, H., Auld, T., Hughes, L., Offord, C. and Baker, P. (2014b). Fuel flammability and fire responses of juvenile canopy species in a temperate rainforest ecosystem. *International Journal of Wildland Fire* 24: 349-360.

Zimmer, H., Auld, T., Benson, J. and Baker, P. (2014a). Recruitment bottlenecks in the rare Australian conifer *Wollemia nobilis. Biodiversity and Conservation* 23: 203-215.

Threatened plant translocation case study:

Symonanthus bancroftii (Bancroft's Symonanthus), Solanaceae

ERIC BUNN[1,2*] AND SHANE TURNER[1,2]

[1] Kings Park Science; Department of Biodiversity, Conservation and Attractions, Western Australia
[2] The School of Biological Sciences, The University of Western Australia, Western Australia
*Corresponding author: eric.bunn@dbca.wa.gov.au

The species

- Low growing (~300 mm) perennial shrub.
- Endemic to SW Western Australia.
- Dioecious.

Threatening processes

- Habitat loss, fragmented remnant bushland.
- Weed competition.
- Predation of seedlings and young plants by feral rabbits.

Deciding to translocate

Symonanthus bancroftii was thought to be extinct in the wild with the last known sighting dating back to the 1940s. In 1997 a single (male) plant was found in an area previously used for road aggregate storage near the wheatbelt town of Ardath in south-west WA, followed by another (female) plant in 1998 after an intensive search. Both plants were tissue cultured (Panaia *et al.* 2000), and a third (female) plant was produced from *in vitro* germinated seed (harvested from an *ex situ* container collection of micropropagated original male and female plants grown in Kings Park) in 2001. It was considered that even with only three genotypes it was worth the risk of translocation, in the event that more plants may be found in the future, and information could be gleaned from a trial translocation would be worth the effort.

Aim of the translocation

The aim therefore was to re-establish two persistent *in situ* populations of several hundred individuals in protected sites in remnant habitats or reserves in the area thought to be the natural range of this species.

Translocation working group and key stakeholders

- Kings Park Science (KPS, formerly BGPA[1]) – to oversee development and implementation, the production of plants and ongoing monitoring and maintenance of translocation sites.
- Department of Biodiversity, Conservation and Attractions (DBCA, formerly CALM[2], DEC[3], DPaw[4]), Western Australia – Wheatbelt region – site selection, implementation and logistical support.
- Bruce Rock Shire.
- Bruce Rock LandCare group.
- WWF (World Wildlife Fund for nature).
- AFF (Australian Flora Foundation).
- Volunteers: local Bruce Rock community and Kings Park volunteers.
- Water Authority of WA.

BGPA[1]– Botanic Gardens and Parks Authority;
CALM[2] – Conservation and Land Management;
DEC[3] – Dept Environment and Conservation;
DPaW[4] – Dept Parks and Wildlife.

Biology and ecology

- Collection limited (<10 times) – last recorded collection in 1940s.
- Dioecious, produces small non-arillate seeds.
- Seeds highly viable, possess physiological dormancy and require smoke to germinate.
- Seed burial studies suggest seeds can survive many years in soil and remain viable.
- Insect pollinated (Ye *et al.* 2007).
- Capsules appear to mature and split, ejecting seeds.
- Recorded from open Wandoo (*Eucalyptus wandoo*) woodland only.
- Mediterranean climate with hot dry summers and cool wet winters.

Site selection

Ardath reserve (Figure 1a) was conveniently located, had good access, long term security and was the site where both rediscovered plants were found. A second site was also chosen (Nangeen Reserve) as this was the next closest (~ 30 km from Ardath) reserve in this region and within the postulated range of *S. bancroftii*. In addition, Nangeen reserve was fenced and regularly monitored by the State Government conservation agency at that time (CALM).

Translocation proposal

Translocation proposals were developed several months prior to planting using a template provided by DEC. These were assessed by independent reviewers to determine whether they met DEC's policies and guidelines. Written feedback was provided after the initial review process with revised proposals resubmitted for additional review and final approval (Taylor *et al.* 2006). An earlier draft Interim Recovery Plan (IRP) prepared in 2001 became the blueprint for proceeding with trial translocations beginning in 2002 at both Ardath and Nangeen sites.

Pre-translocation preparation, design, implementation and ongoing maintenance

Site Preparation:

Both sites were fenced (from 2002) to deter rabbits, irrigation water was provided via on-site tanks and in later trials (2004) both sites were ripped to 1 m to break up hard packed clay soil prior to planting.

Irrigation:

Irrigation lines were laid approximately 1 m apart (up to ~20 m long at Ardath and ~30 m long at Nangeen), translocated plants spaced along lines at ~2 m intervals, drippers (1 L per hr) placed near each plant, with irrigation twice weekly during the first two summers. Each site had two translocation sub-sites that were separate and independently irrigated. In 2007 permission was granted (WA Water Authority) to connect both sites to the local scheme water supply.

Implementation:

Micropropagated plants were produced via tissue culture at BGPA and grown in pots to about 4 months old, hardened off in full sun, then taken to translocation sites to be planted during winter 2002. Later translocations (2005, 2006, 2007 and 2008) were also undertaken using micropropagated plants though from 2006 onwards seedlings generated from *ex situ* collected seeds (Figure 1b) began to be increasingly utilised at the Ardath and later Nangeen translocation sites along with some micropropagated plants. The first translocations (prior to 2004) required a motorised post-hole auger to drill holes ~100–120 mm in diameter and 150-180 mm deep. Following ripping in 2004, digging holes for planting was then able to be done much more easily using hand trowels.

Ongoing maintenance:

Regular weed removal was required especially from August to October. Regular repairs and tank filling were needed for the irrigation system that at first (2002-2003) proved unreliable, and theft eventually resulted in the loss of one tank.

Subsequent actions

One site (Nangeen) has long-term (>20 yr) seed burial experiments (Figure 1c) still current with latest assessment after 6 yrs burial (S. R. Turner, unpublished results). The last major seed collection was done in 2012, however further collections are planned. The recent discovery of a new post-fire population of *S. bancroftii* in 2017 in a nearby reserve (G.J. and B. Keighery; pers. comm.) suggests that seeds can persist in the soil seed bank for many decades between major fire events and further searches in other reserves in the general area of occurrence of *S. bancroftii* may uncover new plants.

Outcomes

- WWF funding allowed the translocation sites to be prepared and translocations went ahead from 2002–2005.
- At the Ardath site approximately 30% of plants survived their first (2004/05) summer, followed by a greatly reduced mortality rate thereafter.
- By 2006 female plants were producing seeds. A study on reproductive biology was conducted on the founder populations at Ardath (Ye *et al.* 2007).
- AFF funding bids were successful in 2008 for several rare species projects, including the *S. bancroftii* project.
- Both translocated populations remain with ~80 plants still surviving across both sites.
- ~10,000 seeds were collected from translocated populations (stored at BGPA).
- Valuable scientific knowledge has been gained on many different facets of this species, as well as the development of general translocation principles – all of which will be invaluable for securing the newly found population and any future finds.
- Tissues cultures and cryostorage of key genotypes has been implemented to support long term *ex situ* germplasm storage as a back-up strategy.

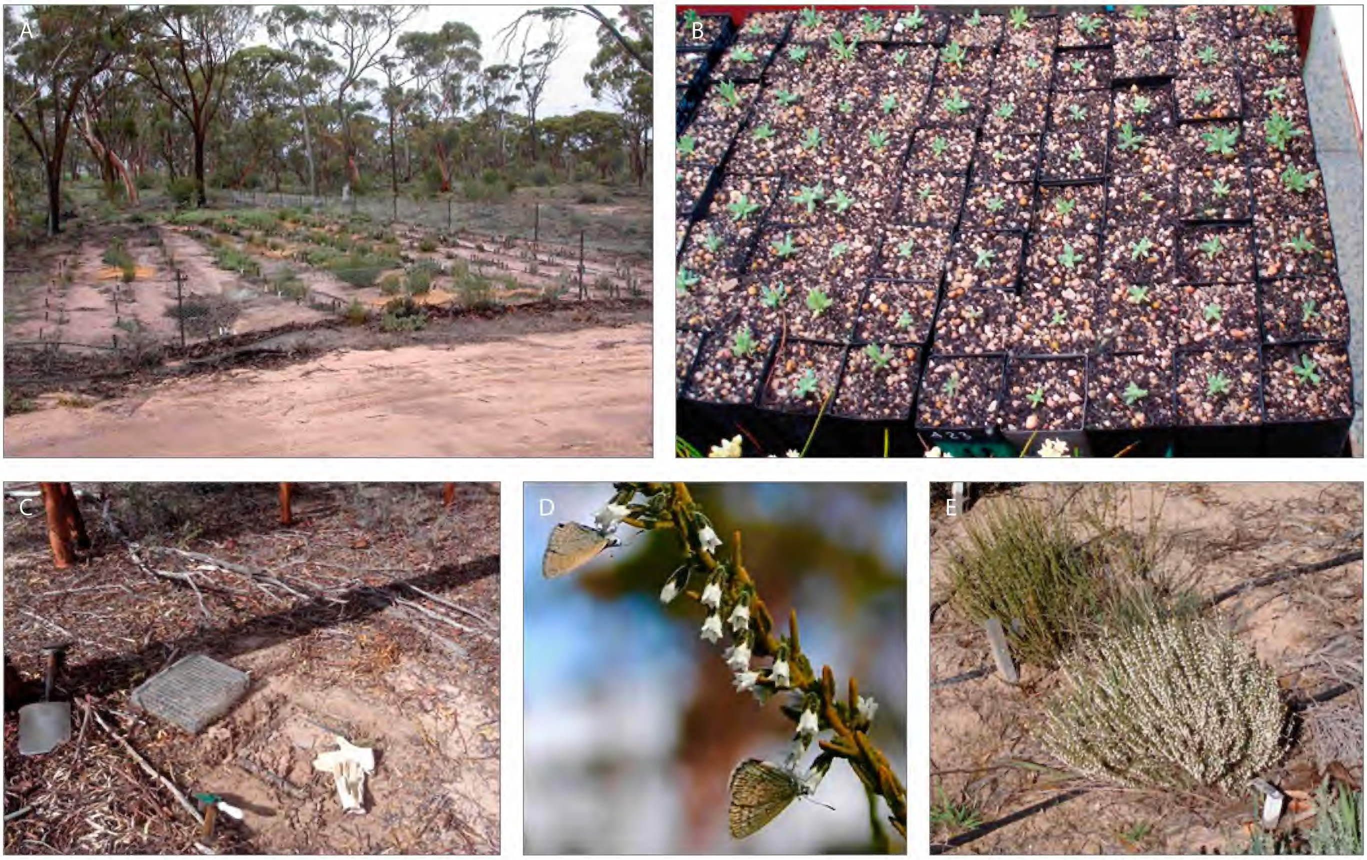


Figure 1a. Ardath translocation site; 1b. Seedlings of *S. bancroftii* being raised at Kings Park and Botanic Garden for translocation; 1c. Seed burial experiment at Nangeen translocation site; 1d. Native butterflies visiting female plant of *S. bancroftii*; 1e. Translocated plants of *S. bancroftii*, male plant front, female plant behind. Photos: a, b, c, e Eric Bunn and d Giuseppe Messina

What we learned

Symonanthus bancroftii was difficult to initially establish in tissue culture until the correct protocols were devised, then micropropagation was successful (Panaia *et al.* 2000). Reliable irrigation was essential to maximise plant or seedling survival during summer in the first two years following transplanting to sites. Precocious flowering was observed after only 2-3 years growth, with pollinating insects frequenting both male and female plants (Figures 1d and e) and abundant seed was produced (Ye *et al.* 2007). Emerging evidence from seed burial experiments suggests that seeds of *S. bancroftii* germinate following after-ripening in soil in response to gibberellic acid or smoke (S.R. Turner, pers. comm.). Based on observations of translocated plants of both male and female *S. bancroftii, if S. bancroftii* is to be protected in the future from threats such as more frequent and intense drought (implicated in climate change models), weeds and feral animals, more needs to be known about its fire ecology and impacts on natural recruitment dynamics. In conclusion, the outlook for Bailey's Symonanthus has improved immeasurably since its rediscovery in 1997.

Acknowledgements

Bob Dixon (former KPS employee, for site preparation, planting, weed control, monitoring), Keran Keys (KPS, for micropropagation of plants for translocations), CALM employees for site selection and assistance with site preparations, Bruce Rock LandCare members and numerous others – volunteers and KPS students, all of whom played vital roles and collectively added great value to the project over the years.

References and further reading

Panaia, M., Senaratna, T., Bunn, E., Dixon, K.W. and Sivasithamparam, K. (2000). Micropropagation of the critically endangered Western Australian species, *Symonanthus bancroftii* (F. Muell.) L. Haegi (Solanaceae). *Plant Cell, Tissue and Organ Culture* 63: 23–29.

Taylor, H., Kershaw, K., Durell, G., Brown, A. and Beecham, B. (2006). *Bailey's Symonanthus (*Symonanthus bancroftii*) Interim Recovery Plan 2006-2011. Interim Recovery Plan No. 225*. Department of Environment and Conservation, Western Australia.

Ye, Q., Bunn, E., Krauss, S. and Dixon, K.W. (2007). Reproductive success in a reintroduced population of a critically endangered shrub, *Symonanthus bancroftii* (Solanaceae). *Australian Journal of Botany* 55: 425-432.

Threatened plant translocation case study:

Tetratheca erubescens, Elaeocarpaceae

CAROLE ELLIOTT[1,2*], KYLIE WILKINSON[3], WOLFGANG LEWANDROWSKI[1], JASON STEVENS[1], SHANE TURNER[1,2]

[1] Kings Park Science; Department of Biodiversity, Conservation and Attractions, Western Australia (formerly Botanic Gardens and Parks Authority, Western Australia)
[2] The School of Biological Sciences, The University of Western Australia, Western Australia
[3] Cliffs Asia Pacific Iron Ore Pty. Ltd., Perth, Western Australi
*Corresponding author: carole.elliott@dbca.wa.gov.au

The species

- Long-lived, lithophytic small shrub with slender, largely aphyllous (leafless) stems arising from a stout woody base.
- Endemic to Western Australia (rank: Vulnerable, Western Australia *Wildlife Conservation Act 1950*).
- Single natural population (covering 3.5 ha) ~500 km north-east of Perth.

Threatening processes

- Mining and exploration (direct removal, indirect effects).
- Limited habitat (restricted to steep cliffs).
- Weed invasion.
- Potential predation (foliage and seed).
- Inappropriate fire regimes.

Deciding to translocate

To mine an iron ore body in the Koolyanobbing Range in Western Australia, Cliffs Asia Pacific Iron Ore (hereafter referred to as Cliffs) received a Ministerial Statement (1054) that agreed to the implementation of the proposal subject to a list of Conditions, including the conservation and protection of *Tetratheca erubescens*. One such condition stated 'establish a new self-sustaining population of at least 313 mature individuals of *Tetratheca erubescens* on a suitable landform that is suitable for the species'. Consequently, translocations would need to be carried out to achieve this Ministerial Condition.

As part of an offset package to mine and subsequently remove *T. erubescens* individuals from banded ironstone habitat, Cliffs were required to undertake translocation research with the aim of contributing to the scientific understanding of the long term recovery and protection of this threatened species. In 2016-2017, a comprehensive research program commenced and was undertaken in collaboration with Kings Park Science (formerly Botanic Garden and Parks Authority).

Aim of the translocation

The objectives of the proposed translocation were to:

- Reduce the overall impact to the species and assist in preserving the number of *in situ* individuals. This would ensure the long-term security of the population in the Koolyanobbing Range and prevent escalation of the species threat status.
- Improve the understanding of methods to successfully translocate *T. erubescens* and assist in the establishment of populations on natural and disturbed landforms, through a comprehensive research program.
- Achieve the Conditions outlined in Ministerial Statement 1054.

Translocation working group and key stakeholders

- Department of Biodiversity, Conservation and Attractions (Kings Park Science) – oversee the development and implementation of translocation (research program, translocation proposal, propagation of material – including engaging a commercial supplier (Natural Area Consulting Management Services), and installation); ongoing monitoring of translocation sites; and reporting to Cliffs.
- The University of Western Australia (School of Biological Sciences) – develop the experimental approach, analyse the data and report research findings.
- Cliffs Asia Pacific Iron Ore – develop translocation proposal; support implementation and ongoing monitoring of translocation; preparation and maintenance of translocation sites; and reporting to the Department of Biodiversity, Conservation and Attractions and relevant stakeholders.
- Department of Biodiversity, Conservation and Attractions (formerly Department of Parks and Wildlife) and Department of Water and Environmental Regulation (formerly Office of Environmental Protection Agency) – advice on development and approval of translocation proposal.

Biology and ecology

- Insect pollinated (most likely buzz-pollinated; Butcher *et al.* 2009).
- Myrmecochorous (ant) and gravity seed dispersal.
- Physiologically dormant seeds (Butcher *et al*. 2011; Elliott *et al.* 2017b).
- Application of warm stratification enhances germination (Elliott *et al.* 2017b).
- Occurs on ridges, cliffs and rocky outcrops associated with ironstone, in shallow red sandy loam.

Site selection

Recipient sites (natural and disturbed) for translocations were selected based on Elliott *et al.* (2017a):

- Habitat species modelling (*i.e*., the likelihood of occupancy; Miller 2015).
- Land tenure and risk of future mining activity.
- Safe and ongoing accessibility to sites.
- Physical and chemical assessment of soils.
- Geology (type and presence of cracks/fissures).
- Location (distance to natural population, elevation, aspect).
- Potential area for future occupancy.
- Resource availability.
- Capacity for site maintenance (*e.g*., irrigation).

Translocation proposal

A translocation proposal was developed by Cliffs in consultation with Kings Park Science, using a template provided by the (then) Department of Parks and Wildlife (DPaW) to guide and provide justification for the translocation. The proposal was submitted to DPaW where it was assessed by several independent reviewers. The proposal met the policy requirements on plant translocations and was granted approval for the translocation process to commence (2017). Translocation approval conditions included submission of an annual report that outlined the following year's translocation plan.

Pre-translocation preparation, design, implementation and ongoing maintenance

Initial sites were selected based on a ranking system and approved by DPaW. For example, sites that had a modelled likelihood of occupancy that was high, a geology consistent with the natural population, habitat potential of establishing a large number of plants, and no risk of future mining activities were ranked as most

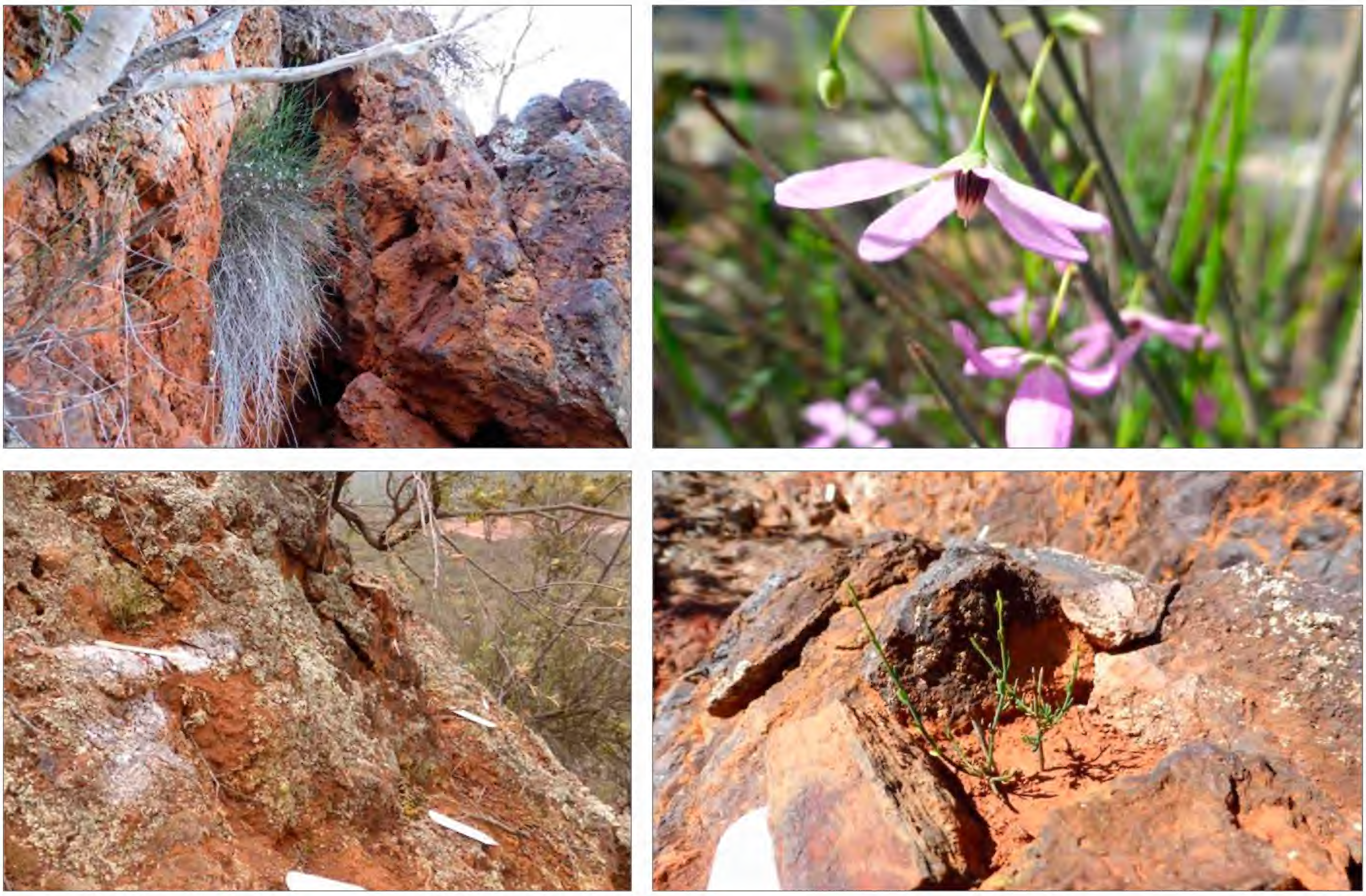


Figure 1. Images of *Tetratheca erubescens* in the natural population and translocations. Top left – Mature plant in natural population at Koolyanobbing Range; Top right – Flower of *Tetratheca erubescens*; Bottom left – Cuttings planted at a translocation located on Koolyanobbing Range (2017 translocation); Bottom right – Two month old translocated plant (cutting derived; 2017 translocation). Photo: Carole Elliott

suitable for translocation. Site preparation involved choosing microsite locations for different translocation material (tubestock, seed) and the drilling of holes (5 cm diameter and 9 cm deep) into translocation site substrate.

Source material (wild collected cuttings and seed) for sites was collected under strict provenancing guidelines, databasing curation (collection, propagation, transportation, labelling, translocation) and licensing conditions. Provenance of material was determined by the species population genetic structure (Krauss and Anthony, 2014) and currently accepted protocol (conservative – protecting existing genetic structure by sourcing material closest to the translocation site) for translocating material of a genetically structured species (DPaW approved). Tubestock and seeding locations were mapped with meticulous continuity of records to ensure source and destination of material was known.

Translocations were designed around comparing the success of planting tubestock and direct seeding. For the translocation of tubestock, we used plants propagated from cuttings that were nine months old. Tubestock treatments that were investigated included planting substrate (cliff or scree slope), potting mix with field soil inoculation, and use of iron-rich fertiliser, irrigation and biodegradable pots. For direct seeding, we investigated the effects of irrigation and seed priming on the emergence and survival of *in situ* seedlings.

The first translocations were implemented in 2017 on natural and disturbed landforms in close proximity to natural populations. Regular irrigation (hand watering) was maintained for one year for each year's translocation program to ensure one summer of augmented soil moisture for a subgroup of treatments. Cliffs maintained the irrigation schedule, and controlled weeds and pests on all sites to ensure the best possible outcome of the experimental translocations.

Monitoring and evaluation

Intensive monitoring of tubestock and direct seeding will be conducted at 3/6 months for the first year of the translocation and then annually thereafter. Monitoring will involve quantification of seedling establishment, survival (sown seed, planted tubestock), growth (seedling and tubestock height, number of stems), health (viable foliage cover) and reproduction.

Early evaluation showed that planting tubestock into natural habitat resulted in ~30% survival two months post-planting (October 2017), which was before the onset of extreme summer heat (December 2017). For direct seeding trials, no seedlings were detected in the following months after sowing, but seeds remain viable allowing for future recruitment. Rainfall was 52% below average for 2017 (BOM 2018).

Subsequent actions

Regular monitoring will be undertaken for the next few years with additional trials planned for installation during the next three winter seasons. Results from earlier trials will be assessed and used as the basis for the development of new hypotheses and treatments for future evaluation.

Outcomes

It appears that *Tetratheca erubescens* can be physically placed into its natural cliff habitat via cuttings with some level of short-term success. Early results suggest that microhabitat placement, seasonal rainfall and access to supplementary water (irrigation) are essential for translocation success.

What we learned

- Spatial habitat modelling is essential for identifying and selecting potentially successful translocation sites.
- Knowledge of population genetic structure is critical to make informed decisions on sourcing and translocating plant material in the wider landscape.
- Fresh seeds are difficult to germinate under controlled laboratory conditions, unless dormancy is broken and a germination stimulant is applied.
- It is possible to have survival of tubestock (after two months) on natural cliff habitat in a semi-arid environment.
- Site amendments play a pivotal role in plant establishment.

References and further reading

Bureau of Meterology (2018). *Climate data online*. Available at: http://www.bom.gov.au.

Butcher, P.A., Bradbury, D. and Krauss, S.L. (2011). Limited pollen-mediated dispersal and partial self-incompatibility in the rare ironstone endemic *Tetratheca paynterae* subsp. *paynterae* increase the risks associated with habitat loss. *Conservation Genetics* 12: 1603-1618.

Butcher P.A., McNee, S.A. and Krauss, S.L. (2009). Genetic impacts of habitat loss on the rare ironstone endemic *Tetratheca paynterae* subsp. *paynterae*. *Conservation Genetics* 10: 1735-1746.

Elliott C.P., Turner, S. and Miller, B. (2017a). Tetratheca erubescens *restoration project report*. Report to Cliffs Asia Pacific Iron Ore Pty Ltd. by the Botanic Gardens and Parks Authority.

Elliott C.P., Lewandrowski, W., Turner, S. and Miller, B. (2017b). Tetratheca erubescens *restoration project 2016 – Report on 2017 variation to original proposal*. Report to Cliffs Asia Pacific Iron Ore Pty Ltd. by the Botanic Gardens and Parks Authority.

Krauss, S. and Anthony, J. (2014). *Population genetic variation and its spatial structure in* Tetratheca erubescens (Elaeocarpaceae). Report to Cliffs Asia Pacific Iron Ore Pty Ltd. by the Botanic Gardens and Parks Authority.

Miller, B. (2015). Tetratheca erubescens *habitat study*. Report to Cliffs Asia Pacific Iron Ore Pty Ltd. by the Botanic Gardens and Parks Authority.

Threatened plant translocation case study:

Grevillea scapigera (Corrigin Grevillea), Proteaceae

BOB DIXON AND SIEGY KRAUSS*

Kings Park Science, Department of Biodiversity, Conservation and Attractions, Western Australia; Botanic Gardens and Parks Authority
*Corresponding author: Siegy.Krauss@dbca.wa.gov.au

The species

- Prostrate, short-lived, fire-killed, disturbance opportunist, woody perennial shrub.
- Endemic to Western Australia.
- No extant natural populations in secure sites.

Threatening processes

- Habitat loss and fragmentation through clearing for agriculture.
- Weeds.
- Salinity.
- Seed and fruit predation.
- Grazing.
- Maintenance of road verges.
- Fertiliser and herbicide drift.

Deciding to translocate

The Corrigin Grevillea was first collected in 1954, and has been known from only 13 small, mainly degraded roadside populations restricted to a 50 km radius area around the Wheatbelt town of Corrigin in Western Australia. The Wheatbelt region has been extensively used for agricultural purposes and over 94% of its 14 million hectares has been cleared. In 1986 the Corrigin Grevillea was presumed extinct. In 1989 a single grafted plant was identified in Royal Botanic Gardens Sydney and was brought to Kings Park in Perth where it was initiated successfully into *in vitro* culture. The following year, naturally occurring plants were discovered near Corrigin, and at the time, up to 35 living specimens were known in the wild. Due to its rarity, the destruction of its habitat, the extreme vulnerability of degraded and isolated roadside remnant populations and the low ability of the species to regenerate on its own, translocation was determined to be critical for the survival of the species *in situ*.

Aim of the translocation

To re-establish at least three self-sustaining populations in the wild in order to improve the conservation status of this critically endangered species.

Translocation working group and key stakeholders

- Botanic Gardens and Parks Authority, Western Australia.
- Department of Biodiversity, Conservation and Attractions, Western Australia.
- Australian Nature Conservation Agency (Commonwealth Government).
- Local Corrigin and Landcare community.
- Kings Park volunteer Master Gardeners.

Biology and ecology

Grevillea scapigera grows after winter rains, and flowers September – December. Inflorescences are produced on new growth and over 1000 flowers can be observed at one time on an average 1.5 m diameter plant. Flowers are protandrous (male parts mature before female parts), strongly scented and produce abundant nectar. These remain receptive for pollination for up to 4–5 days. Flowers are pollinated by a range of insects, especially Hymenoptera and Lepidoptera. Ants frequently visit flowers to feed on nectar, but are unlikely pollinators. Pollen has been successfully placed in cryostorage at Kings Park with no significant decline in viability.

Individual plants flower after 1 year (earlier under cultivation), live ca. 7–9 years, and are killed by fire. Seed is dehisced soon after maturity. On average, three to five fruits per inflorescence are produced naturally, each containing 1 or 2 seeds. Seeds have high viability (usually > 90 % germination *in vitro*) and remain viable for at least four years. Seeds generally require soil disturbance to germinate, although inter-disturbance recruitment can occur following heavy summer rain. Ants could be an important factor for the survival, germination and dispersal of seeds. High levels of seed predation by insects, mainly weevils and looper caterpillars, as well as parrots, occurs.

The Corrigin Grevillea is difficult to propagate by conventional horticultural methods. However, semi-hardwood cuttings, at the correct stage of growth, gave good strike rates. Tissue culture facilitated the production

Grevillea scapigera **translocation site 1: Twenty years after the site was ripped, fenced and planted. Planting continued for several years and the majority of experiments were conducted on this site due to ease of access. Plants continue to germinate, flower and seed between disturbance events. Native vegetation covers most of this former airstrip. Photo: Bob Dixon**

Grevillea scapigera **translocation site 2: Good vegetation cover and the most species rich site. Some** ***Grevillea scapigera*** **seedling germinants appeared in 2017. Due to the numbers of highly competitive** ***Gastrolobium spinoslum*** **on site** ***G. scapigera*** **seedling numbers have declined over the years. Photo: Robin Campbell**

of a large number of plants in a relatively short time. Genetically selected clones were secured *in vitro* and have also been cryopreserved to ensure long-term protection of diverse germplasm.

Seed germination treatments trialled include heat, smoke (aerosol and water), gibberellic acid, standard and specific scarification and a mixture of treatments. A precise method of scarification has been shown to be the most effective, and produces average germination rates of over 50%.

Initial genetic analysis was carried out on all known plants at the time (Rosetto *et al.* 1995) and showed high genetic variability and little differentiation among surviving populations. This suggested that existing plants comprised a single genetic provenance, and that plants could be pooled with little risk of outbreeding depression. Ten genotypes that included over 87% of the known genetic variability were chosen for propagation to establish the translocated population (Rossetto *et al.* 1995).

Site selection

Possible sites were investigated within the geographic range of *G. scapigera*. Three were selected provisionally: two re-introduction sites where the species was still present in small numbers and one introduction site. Two more sites were added later, where the species had not been recorded before. The latter sites were selected as the last remaining native vegetation remnants in the region, very close to known sites for the species. Soil samples collected from all sites were compared with samples from the largest remaining population and found to be very similar. The vegetation at all sites was alike and defined as scrubheath or kwongan, with many species occurring in all sites.

Translocation proposal

A key step was the appointment of a recovery team, which included researchers from Kings Park, staff from the (then) WA Department of Conservation and Land Management (CALM), the Australian Nature Conservation Agency and members of the local community.
The involvement and enthusiasm of the local community was very important and interest was kept high through regular meetings and site visits with local Landcare groups and schools. The proposal was assessed by two independent reviewers as to whether it met CALM's policy on plant translocations, before being given approval for the translocation process to commence.

Pre-translocation preparation, design, implementation and ongoing maintenance

The Corrigin Landcare group provided and erected an electric fence at one site in order to protect the translocated plants from trampling by the many macropods found in the area. Trials were carried out on the exclusion of grazing by rabbits (which were capable of entering the fenced areas) by using wire cages. The necessity for shelter was also clarified by trial planting in sparse native vegetation and in a cleared area, the former initially giving much better results, and further trials indicated plants often performed better in cleared open areas. The other 2 sites (0.2 ha each site) were fenced with rabbit proof wire to exclude rabbits. Three plantings were initially carried out, in July 1993 (235 plants), June 1994 (140 plants) and June 1995 (52 plants). Phytosanitary guidelines for the translocation of *G. scapigera* were prepared and adhered to, the guidelines were primarily to reduce the risk of introducing diseases, particularly root pathogens, and weeds to the translocation sites. No flowering plants were translocated, avoiding the risk of inter-species pollen transfer within the nursery and resulting hybrid seed of nursery origin. Ten clones representing 87% of the known genetic diversity of the species were used in the initial translocation. Additional genotypes have been added over time as new wild plants were found. Translocations using large numbers of plants derived by tissue culture were begun in 1996 after pilot studies indicated translocation was feasible.

Monitoring and evaluation

Monitoring began and continued every month following planting, for the first 2 years, to record information on survival and growth rates, flowering patterns, numbers of flowers and seed produced as well as damage caused by pests such as rabbits, parrots and seed eating insects. Monitoring for the first 2 years indicated vast seasonal variations which may in part be due to the quality of the greenstock (plants) at time of planting, vagaries of the weather (lack of rainfall) and wide variation between clones.

The introduction of a trickle irrigation system improved the success rate of plantings and increased seed production when compared to non-irrigated plants (Dixon and Krauss 2001). However, the life span of irrigated plants was substantially reduced.

Monitoring of sites was then reduced to twice a year, recording survivorship, pests, weeds, estimates of seed production and any new recruits of seedlings. There was a wide variation in seed production – the best site produced over 1 million seeds in 2006.

Genetic erosion between founders and offspring was assessed in 1999 at one translocated site (Krauss *et al.* 2002). Poor genetic fidelity in the founding population was found (8 clones, not 10, were present, and 54% of all plants were a single clone), and significant erosion of genetic variation (offspring were 22% more inbred and 20% less heterozygous than parents). Ultimately, the genetically effective population size of the founding translocated population was estimated to be two. Our results highlighted the difficulty of maintaining genetic fidelity through a large translocation program. This genetic erosion was addressed by avoiding over-represented clones and increasing the numbers of poorly represented clones. Many of these poorly represented clones were recovered from *ex situ* cryogenically or tissue culture stored germplasm. However, further research is required to identify the intensity of inbreeding depression associated with elevated inbreeding in these translocated populations, and to assess the long-term consequences.

Predation of seed is a major problem. Insect damage is very high, the two main pests are a native weevil and looper caterpillar. These can be controlled by the careful use of pesticides spraying 3 weeks before seed harvest. Cape Weed *Arctotheca calendula* (Asteraceae) is a problem, especially after the exclusion of rabbits. The use of low rates of the non-selective herbicide Lontrel™ has been very effective for its control.

Subsequent actions

In 2008, an Interim Recovery Plan (IRP) was published (DEC 2008). The objective of this IRP is to abate identified threats and maintain and/or enhance the habitat of natural and translocated populations; gain an understanding of the recruitment dynamics of the species; obtain *in situ* recruitment (through artificial or naturally occurring disturbance), maintain the soil seed bank and ensure the long-term preservation of the species.

***Grevillea scapigera* translocation site 150 year seed burial trails. 2017 seed harvest (7th harvest after 14th years in the ground). Kings Park and Botanic Garden Volunteer Master Gardener Len Burton and Bob Dixon former Manager Biodiversity and Extensions. Photo: Robin Campbell**

***Grevillea scapigera* inflorescences. Photo: Siegy Krauss**

Additional recovery actions have included:

- Appropriate land managers have been made aware of the location and threatened status of the species.
- Declared Rare Flora (DRF) markers have been installed at all roadside populations.
- Dashboard stickers and posters that describe the significance of DRF markers have been produced and distributed.
- Approximately 3,300 seeds from 21 plants are stored in DBCA's Threatened Flora Seed Centre (TFSC) and 2,000 seeds are stored at the Botanic Gardens and Parks Authority (BGPA) for propagation and research purposes.
- BGPA holds 17 different clones *in vitro* and in cryostorage.
- Opportunistic surveys in areas of suitable habitat following disturbance is ongoing.
- The Great Southern District Threatened Flora Recovery Team is overseeing the implementation of this IRP and reports annually on progress.
- Further genetic research (Ayre 2014) showed that measures implemented to control the erosion of genetic diversity have been successful, with heterozygosity constant and mean effective number of alleles increasing in third generation plants.

Outcomes

The original aim, which was to establish three self-sustaining translocated populations, was met and exceeded with the establishment of > 200 adult plants each, in secure, threat-free sites. In 2014, there were an estimated 455 individuals across all translocation sites. At the Corrigin airstrip site, there were 150 plants present in 2014, all but two from *in-situ* germination. In 2017, 307 plants were present. Regular contribution of seed to the soil seedbank, recruitment and survival of plants continues. All sites are well vegetated with indigenous species and recent monitoring indicates species richness, flora and fauna, continues to increase. The seed burial trials, initiated in 2003, show seed viability remains very high after 14 years, averaging 76%. Sites have not been actively managed for several years but appear to be self-sustaining mainly due to indigenous species outcompeting weeds.

What we learned

- It is possible to establish new populations of this species.
- Using an experimental framework when establishing translocations can provide critical information for long term translocation success.
- Fencing, weed control and summer watering improves survival of planted seedlings.
- Good quality (weed free, biodiverse, well vegetated) sites are important for translocation purposes.
- Network (contact people) on a regular basis to maintain professional and voluntary partnerships. Volunteers were essential due to the volume of work, lack of resources and to obtain funding (grants).
- Rabbit-proof fencing was critical, with a minimum area of 0.2 ha to allow expansion of plantings and/or future inclusion of other rare species on site if desired.
- Irrigation systems significantly improved survival rates, increased growth rates, flowering and seed production, but can reduce the life span of plants.
- Large numbers of plants en-masse can lead to an increase in seed predation.
- It was important to monitor on a regular basis *e.g.*, once a month at least for the first 2 years. This includes checking on pests/diseases, fencing and maintaining watering systems.
- Monitoring genetic variation can assist in management of genetic diversity through time.
- Maintaining genetic stock for a long period *e.g.*, cryostorage and/or seed storage is critical for managing worst-case scenarios of extinction in the wild.
- Plants generated from cryostored material performed well on site and produced large quantities of viable seed.
- Monitoring for multiple generations (>20 years for *G. scapigera*) is required to determine if translocated populations are naturally self-sustaining in the long-term.

References and further reading

Ayre, B. (2014). *Genetic erosion and its consequences for the recovery of* Grevillea scapigera. Hons thesis, UWA.

Bunn, E. and Dixon, K.W. (1992). *In vitro* propagation of the rare and endangered Corrigin Grevillea, *Grevillea scapigera* A. S. George (Proteaceae). *HortScience* 27 (4): 261-262

Department of Environment and Conservation (2008). *Corrigin grevillea* (Grevillea scapigera) *Recovery Plan. Interim Recovery Plan No. 224.* Department of Environment and Conservation, Perth, Western Australia.

Dixon, B. and Krauss, S. (2001). Translocation of *Grevillea scapigera*: is it working? *Danthonia* 10:2, 2-3.

Krauss, S.L, Dixon, B. and Dixon, K.W. (2002). Rapid genetic decline in a translocated population of the endangered plant *Grevillea scapigera*. *Conservation Biology* 16:986-994.

Rosetto, M., Weaver, P.K. and Dixon, K.W. (1995). Use of RAPD analysis in devising conservation strategies for the rare and endangered *Grevillea scapigera* (Proteaceae). *Molecular Ecology* 4:321-329.

News from the Australian Seed Bank Partnership

Note from ASBP: In this issue of APC, the News from the ASBP focuses on a Greening Australia project that sought to restore remnants of Cumberland Plain Woodland in Western Sydney. This project serves as a good example of how the removal of woody weeds can be combined with whole-of-community ecological restoration and targeted plant translocations to restore native ground layer vegetation in a threatened ecological community.

Whole Community Restoration and Translocation at Parrott Farm Reserve Narellan

PAUL GIBSON-ROY

Greening Australia
Corresponding author: PGibson-Roy@greeningaustralia.org.au

Site background

Parrott Farm Reserve is located at Narellan in Sydney's south-west. It was originally a part of a 100-acre land grant made to William Parrott, an employee of John Macarthur. The grant was made in 1810 and occupied the corner of present-day Camden Valley Way and Richardson Rd to Lodges Road. Today, much of the grant footprint is taken up by the Camden Golf Course (on lease from Camden Council) but also includes two areas of adjoining Cumberland Plain Woodland varying in quality from good to degraded. Within both bushland areas are populations of the threatened Spiked Rice Flower (*Pimelea spicata*). Higher quality areas of bushland are dominated structurally in the upper canopy by Grey Box (*Eucalyptus moluccana)* (with very few old trees and dense sapling regrowth), and Sweet Bursaria (*Bursaria spinosa*) (as a dense mid storey). Small pockets of native ground layer vegetation exist within the bushland but are largely restricted to track edges due to high resource competition (primarily competition for light) from the mid- and overstory strata. The bushland areas have been managed since 2007 by the then Catchment Management Authority and now Greater Sydney Local Land Services in conjunction with the Camden City Council and Camden Golf Club

Rationale for action

Alongside one of the bushland areas between the land occupied by the golf club were zones ~1.5 ha in size heavily dominated by the woody weed African Olive (*Olea europaea* subsp. *cuspidata*) (formerly subsp. *africana*), and lesser open areas densely covered by Kikuyu Grass (*Pennisetum clandestinum*) (Figure 1). Early flora surveys showed there was little native vegetation present within these areas except for a small number of large Eucalypts growing above the weedy strata, with native ground layer vegetative cover restricted to < 1%.

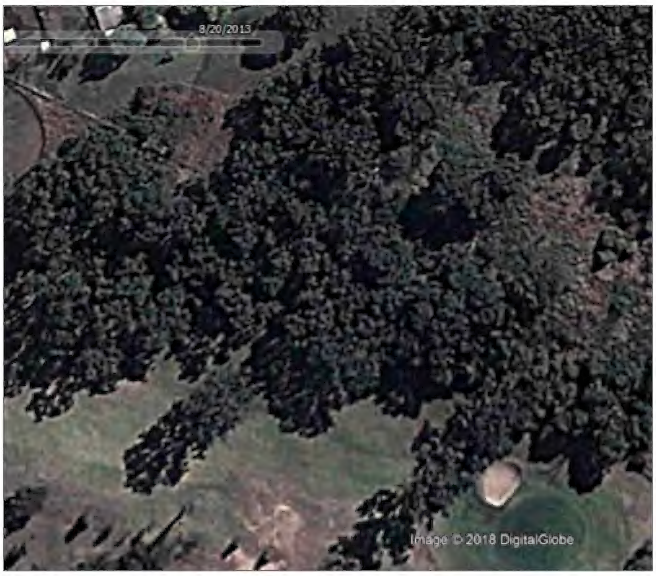


Figure 1. Parrot Park Reserve 2013 showing native bushland area to right of image and Olive/Kikuyu dominated area to left/centre. Image (c) 2018 DigitalGlobe, Google

Because of the degree of weed infestation in these areas it was thought they were unlikely to naturally revert to higher quality native composition and so were considered candidates for implementing more intensive ecological restoration and translocation interventions such as demonstrated by other groups across SE-Australia in recent decades (Gibson-Roy and Delpratt 2015). Thus, in 2015 the site's primary land managers - Greater Sydney Local Land Services and Camden Council, established a partnership with Greening Australia to develop a restoration plan to restore native vegetation within a 0.8 ha area. The project was financially supported through federal Caring for Our Country (CfOC) and NSW Environment [Trust] funding (as well as through considerable in-kind support from the project partners).

Restoration and translocation goals

There were several key goals of the project which sought to combine the closely aligned disciplines of ecological restoration and plant translocation to effectively change the compositional state of the site from one dominated by exotic vegetation to one dominated by native species, and in this process return species from a threatened ecological community as well as an individual threatened species to the site. Both the latter actions required securing collections of wild seed and/or cuttings (in the case of the Spiked Rice Flower) and growing these on as native seed crops from which suitable quantities of seed and/or plants were then available for these reintroductions.

Project constraints

There were several major constraints linked to this site which might normally discourage groups from undertaking ecological restoration or plant translocation. The most pressing among them were:

- A highly modified and topographically uneven soil profile associated with long term farming practices and latter development of the golf course. This left the site with highly heterogenous and unpredictable characteristics (*i.e.*, agricultural residues, construction debris, patchy textural and nutrient profiles and very high weed seed/bud loads).
- Extremely dense stands of established African Olive (to ~80–95%) and smaller areas of very dense Kikuyu Grass (to ~10%).
- Very little native seed resources available in the surrounding bushland (or nearby region) to meet restoration goals.

In late winter/early spring 2016 the Olive vegetation was removed using ‘trittering’ machinery which essentially mulched the aboveground woody material to ground level (and just below) (Figure2a). Areas of Kikuyu Grass were treated with chemical herbicides. Following these actions, the coarse Olive mulch layer and dead Kikuyu herbage was scalped off to a depth of approximately 150 mm using earth moving equipment to remove weed seed and bud material. Further soil works were then undertaken to create a relatively even surface, while still retaining the broad contours of the site (Figure 2b). Six large eucalypts resident within the weedy vegetation were retained as were several large fallen logs, which were re-located strategically within the footprint (Figure 2c).

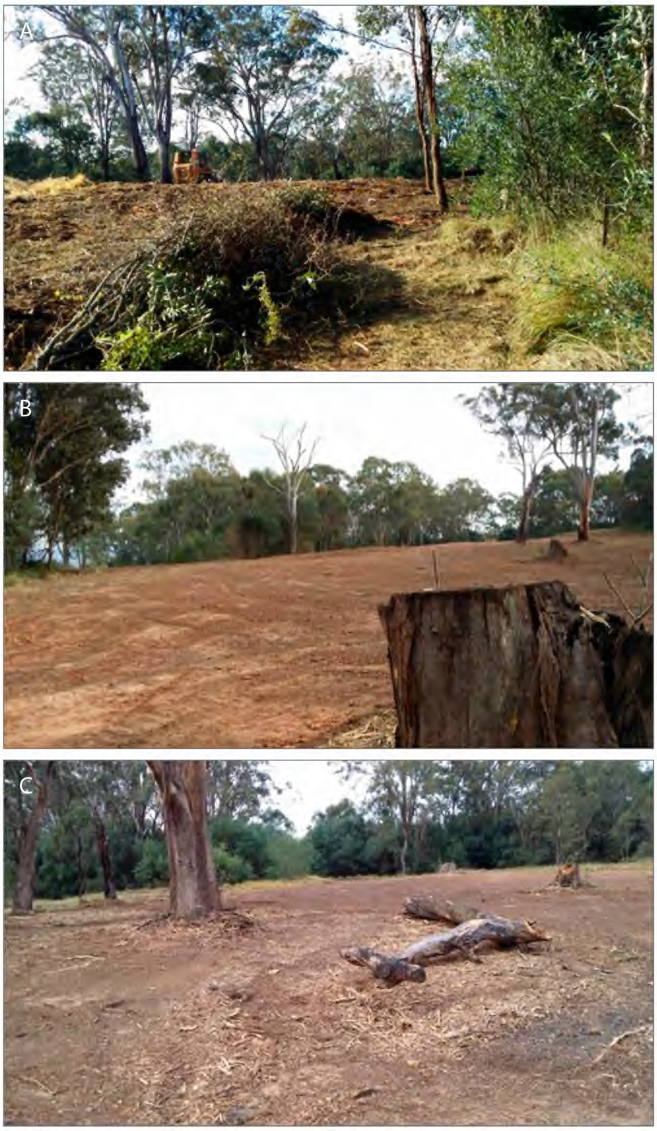


Figure 2a. Mechanical Olive removal. b. Soil surface flattened for seeding. c. Fallen logs placed within the seeding footprint. Photos: Paul Gibson-Roy

In late spring 2016 the cleared and prepared area was direct seeded with native ground layer species (Figure 3a). Over the following two years this vegetation emerged and established as the dominant ground layer (Figure 3b and c). And although several subdominant herbaceous weed species remain as components of the vegetation (and are managed accordingly) neither African Olive nor Kikuyu are present to any discernible degree. To improve management options within the seeded areas species were originally sown as discrete bands of grasses or forbs. Monitoring of the vegetation in December 2017 revealed 19 native grass and 36 forb species occurring at average densities of 13 grasses per square meter (in grass bands) and 40 forbs per square metre (in forb bands). In addition, another six non-sown native species re-emerged from the seed/bud bank over time within vegetation gaps. Across the whole site there were only six exotic grasses and 16 exotic forbs per square metre. At this time natives dominated the ground layer in terms of vegetative cover (30% native, to 12% herbaceous weed), while ample opportunity for further recruitment existed via the presence of canopy gaps (58% bare earth).

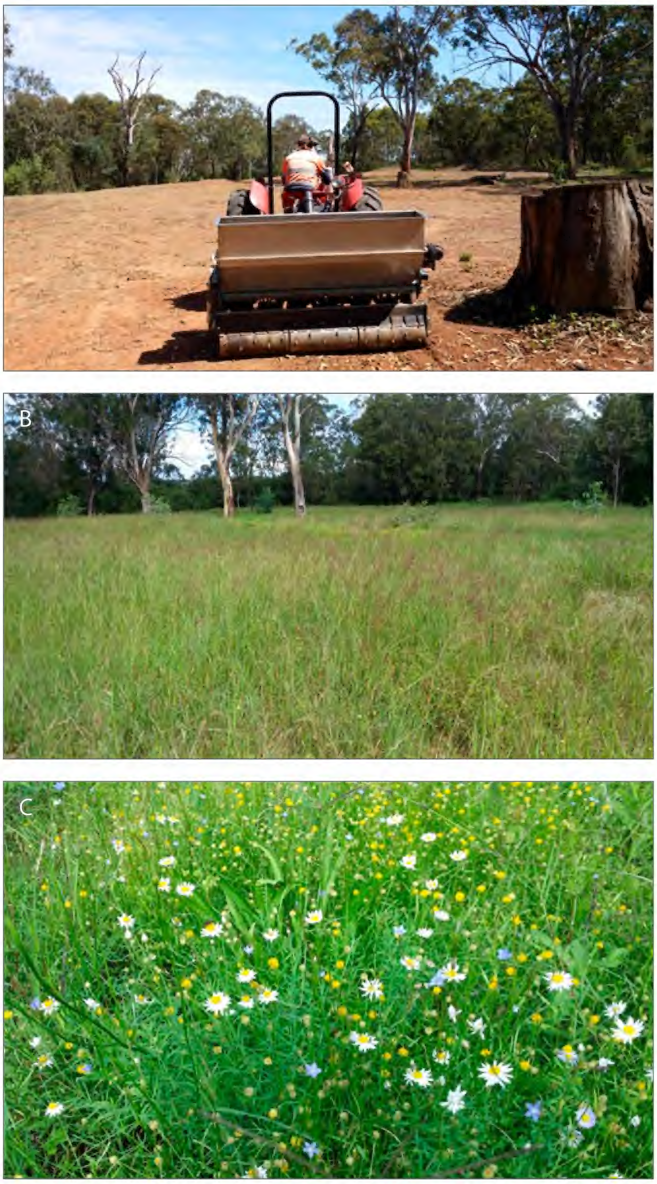


Figure 3a. Direct seeding with a high diversity native seed mix. b. Native grasses covering previously Olive dominated footprint. c. Dense sweeps of native forbs in flower. Photos: Paul Gibson-Roy

In autumn 2017 and autumn 2018 Spiked Rice Flower plants (propagated from cuttings grown as seed production area (SPA) crops) were installed as block plantings within the re-established native sward (Figure 4). Planting blocks were hand watered weekly for one-month post-planting. In total 90 individuals were translocated thus expanding the range and population size of the nearby bushland populations. All plants were tagged, and their survival monitored. As of late-spring 2018 90% of plants had survived. It is envisaged that ongoing translocations of this species will occur at the site as plants become available from the production population.

Summary

That the project sought the ambitious goals of replacing an intensely competitive woody weed (in the form of African Olive) with a diverse mix of native ground layer species from an Ecologically Threatened Community as well as translocating within this a nationally threatened species (Spiked Rice Flower) demonstrates the feasibility of such thinking. The project's success highlights the importance of several key components which were:

- Large scale machinery can be extremely effective in dealing with woody weeds and inappropriate soil conditions.
- Seed production approaches are an ideal way to increase seed resources from scarce wild populations for use in direct seeding.
- Seed production areas are ideal repositories for cutting crops of threatened species for latter or ongoing reintroductions.
- Combining whole-community ecological restoration with plant translocation can increase the efficacy and significance of project outcomes.

Projects of this type demonstrate that with effective partnerships, proper planning, resourcing and application that areas of degraded urban vegetation can be transformed into areas of highly valuable native biodiversity. These also offer considerable habitat value for fauna and amenity value for local communities. It is hoped that in future other councils and land management agencies will take on these approaches and thinking to increase native biodiversity within their cityscapes.

Reference

Gibson-Roy, P. and Delpratt, J. (2015). The Restoration of Native Grasslands in *Land of Sweeping Plains – managing and restoring the native grassland of south-eastern Australia*. Eds, Williams, N. Marshall, A. and Morgan, J. CSIRO Publishing. 331-389.

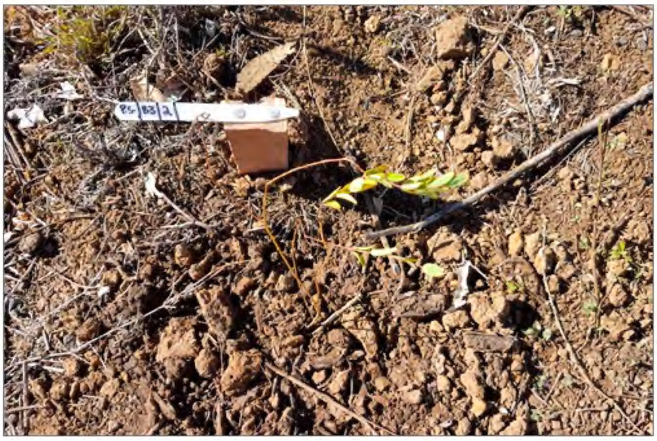


Figure 4. Spiked Rice Flower plants were tagged and pegged for monitoring purposes. Photo: Paul Gibson-Roy

ANPC workshop report

Western Landcare Youth Network Workshop
Native Plant Identification Workshops – Broken Hill and Beyond

MARTHA GOUNIAI AND MARTIN DRIVER

In early September 2018, despite continuing drought conditions in far west NSW, it was decided to proceed with planned native plant identification and use workshops with the Western Landcare Youth Network at Broken Hill. Western Landcare and program co-ordinator Martha Gouniai and participants from the Western Landcare Youth Network took part in the Aboriginal Cultural Heritage and Plant identification training day at Mutawintji National Park as part of the annual agricultural mentoring program.

Having participated in a range of monthly workshops focused primarily on agriculture it was time for the participants to learn about the flora and landscapes that underpin grazing in Western NSW, and the traditional cultural uses of many of the arid zone species in the area. Led by Martin Driver from the ANPC and Mutawintji Park Rangers, the group was taken along a cultural tour of the sacred sites the park protects. Along their walk many plant species were identified and discussed for their productive grazing, cultural and environmental values, and the sheer beauty and adaptations of many of the plants. The need for management and various natural and induced restoration and regeneration strategies were also discussed.

For those who haven't visited Mutawintji it is well worth the trip, especially after better rainfall conditions. The Park contains a significant geological and cultural desert landscape of rugged rocky ranges, rock pools and Red Gum lined creek beds that would have been a significant refuge for plants, animals and first nation peoples. Mutawinjti still plays that role today and needs to be further protected from goat predation to maintain regeneration of the precious flora that still persists.

The Youth Network had also invited Menindee Central School to join them for their workshop. Three students and three staff from the school were able to attend adding their own cultural knowledge to the experience. In total a group of 20 enjoyed the day's workshop which included a history of Barkindji ceremony, an understanding of the creation and preservation of rock art hand stencils, traditional cooking techniques and local bush tucker as well as a wood carving workshop using harvested Mulga wood.

Due to the drought conditions, planned landholder workshops on native plant identification, use and management on Western NSW stations have been postponed to be held under better conditions. Opportunities have also been identified for both the Rangers and landholders for future workshops on identification, management and future potential commercial opportunities using some of the native plants or on plant and landscape tourism and education.

Native Plant Identification Workshops. Photo: Martha Gouniai

Genetic analysis of *Banksia marginata* from central Victoria

DR ADAM MILLER

Centre for Integrative Ecology, School of Life and Environmental Sciences, Deakin University, PO BOX 423, Warrnambool 3280 VIC
Corresponding author: a.miller@deakin.edu.au
Partners: Deakin University, Connecting Country, Kara Kara Conservation Management Network, La Trobe University, CSIRO, Australian Network for Plant Conservation

Summary of project findings

A genetic study of *Banksia marginata* from the central region of Victoria was performed to determine contemporary patterns of population connectivity and genetic diversity. A primary driver of this research was to identify genetically diverse seed sources for assisting regional restoration efforts (including the establishment of seed production areas (SPAs)), and inbred remnants in need of genetic rescue. Genetic analyses were performed on 16 remnant stands spanning the central region of Victoria, with results indicating significant genetic differentiation among sample locations and all remnants being isolated self-recruiting populations. The estimation of relatedness indicated that remnant stands consist of highly related individuals, with an average of 16% of sampled individuals being direct relatives. These findings indicate limited genetic connectivity among remnant *B. marginata* stands from the central region of Victoria, suggesting minimal cross pollination between remnants, and that recruitment for the past few generations has been primarily from locally produced seed.

The observed patterns of local genetic structuring may reflect contemporary demographic processes associated with population fragmentation following European settlement. Allelic diversity appeared to be significantly lower in some remnants, while estimates of heterozygosity were comparable across remnants – a pattern typical of recent local population decline. This was further supported by additional analyses indicating that most remnants across the central region of Victoria have suffered from recent genetic bottlenecks. Therefore, it is likely that the observed patterns of genetic differentiation among remnants is due to recent reductions in local population sizes, and connectivity among remnants. These findings raise questions about the potential factors influencing spatial patterns of pollination/gene flow in *B. marginata*, and highlight the need for further studies into the synchrony of plant phenology among remnants, pollinator behaviour, and landscape factors influencing pollinator movement.

Findings from this study suggest that many small and isolated remnants in the region are highly vulnerable to inbreeding in the absence of managed intervention. It is uncertain if local populations are already suffering from inbreeding effects, or whether the species can tolerate some level of inbreeding, as this was not explicitly assessed in this study. Research evaluating the relative fitness of small isolated vs large contiguous populations will help provide some clarification (*i.e.*, seed viability, flowering intensity, recruitment). Theoretically, a 20% gene flow/migration rate is needed to reduce the negative effects of inbreeding; but this study demonstrates that gene flow is currently inadequate (zero migration in most cases). Restoration efforts should focus on increasing local population sizes and the connectivity among remnants to reduce inbreeding threats.

Selecting appropriate seed sources for restoration activities is important for reducing inbreeding threats and enhancing the environmental resilience of *B. marginata* remnants by selecting seed mixes with a broad genetic base. From this study as well as a recent study on *B. marginata* from the Victorian Volcanic Plains (VVP; which produced similar results), the following recommendations are provided to help guide future conservation and restoration planning:

1. Patterns of genetic diversity are comparable across remnants included in this study, suggesting these are suitable for future seed collection activities. Other remnants in the region may be suitable, but managers should focus on the larger remnants to capture maximum genetic diversity and avoid smaller and potentially inbred remnants.
2. Smaller remnants (*i.e.*, <100 individuals) are more at risk of inbreeding and extirpation than large remnants (*i.e.*, >100 individuals). This should be used as a framework for prioritising restoration efforts.
3. SPAs on the VVP could be used to address possible seed shortfalls and provide regionally generic seed mixes for establishing new populations or augmenting existing populations. SPAs will also reduce the pressure from struggling remnants currently targeted for seed collection. SPAs should include source material from multiple provenances across the local region to ensure seed mixes have a broad genetic base. Including composite (see point 4) and climate-adjusted provenances is recommended (see point 5). Linda Broadhurst (CSIRO) and I can provide specific advice for the development of Banksia SPAs if required.
4. Augmenting existing remnant seed mixes should aim to include a composite of local provenances (~60%), and material from non-local sources (~40%; SPA

regionally generic seed mix). This calculated approach will broaden the genetic basis and adaptability of the population without compromising locally adapted genes/traits (if present). When establishing new populations when no local provenance is available, diverse multi-provenance seed mixes should be adopted and sourced from the SPA once established.

5. The combination of future climate change and lack of gene flow in *B. marginata* should encourage managers to consider supplementing local seed mixes with 'climate ready' seeds. This can be achieved by carefully selecting seed from climates that match the predicted future climates for your local region. There are several programs underway in this space and both Linda Broadhurst (CSIRO) and I can provide advice if required.

The recommendations provided above are based on the outcomes of the genetic study alone, however other factors will require consideration when investing in restoration projects. The results presented here do, however, provide an important resource for guiding future management decisions associated with the conservation of *B. marginata* in the central region of Victoria. This study provides new insights into the species' biology and ecology and highlights the vulnerability of many *B. marginata* remnants due to future inbreeding threats and environmental change, and the urgent need for intervention. This study also indicates the need for further research to characterise factors that limit gene flow at fine spatial scales for this species. For example, research on characterising pollinator diversity, their behaviour, and landscape influences on pollen movement would be extremely beneficial. Furthermore, comparing plant phenology across remnants with pollen viability would assist in identifying potential barriers to gene flow among remnants.

The methodology and results of this study are detailed below.

Methods

Field collections

A total of 16 remnant *B. marginata* stands from central Victoria were sampled for genetic analysis (Table 1). Leaf tissue was collected between winter and spring, 2017, with a maximum of 30 one-gram samples of fresh growth collected from individual trees from each site. At each site, individuals were sampled at random and adjacent plant sampling was avoided to minimise the risk of sampling suckers and close relatives. Individual samples were given unique identifiers, preserved in paper coffee filters and then rapidly desiccated with silica gel, to ensure minimal degradation of genetic material. Geospatial data for each collection site was not provided, meaning that spatially explicit genetic analyses could not be performed.

Table 1. Site information, corresponding codes and sample sizes for each of the 16 collection sites.

Collection site	Code	n
Balborra	BAL	4
Billy-Ho Nature Walk	BHO	6
Burke and Wills track north	BWN	7
Burke and Wills track south	BWS	12
Havistock Hill	HAV	20
Koala Park	KOA	14
Long Point	LOP	30
Mt Beckworth	MBK	17
NYC	NYC	12
Orr Street	ORR	4
Pastoria East	PSE	25
Petticoat Slatery Creek lower	PSL	17
Petticoat Slatery Creek lower	PSU	5
Smeaton Cemetary	SMC	5
Tooboorac	TOO	25
Wilsons Rd, Kooroocheang	WIL	5
Whyte Rd, Kara Kara	WTE	30

DNA extraction and genotyping

Genomic DNA was extracted using a 30 mg sample of plant tissue from each individual specimen using the NucleoSpin® 96 Plant II protocol (Machery-Nagel Inc., Düren, KO, GER), and DNA quantitation was then performed as per the QuantiFluor® dsDNA System (Promega Inc, Madison, NY, USA). *Banksia marginata* DNA samples were genotyped at 10 microsatellite loci using a composite of genetic markers developed by He *et al.* (2013) and Fatemi *et al.* (2014), with additional markers also developed in the present study (Table 2). To distinguish PCR products upon capillary separation, primers for the ten microsatellite markers were tagged with a unique fluorescent label during PCR using the method outlined in Blacket *et al.* (2012). Reactions matrices for PCR amplification consisted of 5 µl Qiagen multiplex mix (Qiagen, Chadstone, Victoria, Australia), 4 µl of primer mix (0.2 µM of each primer) and 2 µl of template DNA. PCR conditions consisted of an initial 15 min denaturing step at 94 °C, followed by 40 cycles of 94 °C for 30 s, 59 °C for 1:30 min, and 72 °C for 1:00 min, with a final extension step of 60 °C for 30 min. Genotyping was then performed using an Applied Biosystems 3730 capillary analyser and product lengths were determined relative to a GS500LIZ_3730 size standard. Fragment analyses were conducted using an ABI3730 XL DNA analyser. Microsatellite profiles were examined and scored manually and assessed for polymorphisms using GeneMapper version 4.0 (Applied Biosystems).

Table 2. List of microsatellite loci used in the current study

Locus	Allelic range	# of alleles	Reference
BM11	192 - 202	3	This study
BM12	213 - 258	13	"
BM2	167 - 190	5	"
BM22	220 - 254	11	"
BM27	123 - 156	13	"
BM37	260 - 284	9	"
BM13	170 - 182	20	"
BM4	241 - 248	11	"
BR3	155 - 175	21	He *et al.* 2008
Bint05VIC	228 - 265	9	Fatemi *et al.* 2013
Bint07NED	174 - 183	5	Fatemi *et al.* 2014

Population genetic analyses

Descriptive statistics were calculated for the microsatellite data using FSTAT ver. 2.9.3 (Goudet 1995) including: (1) allelic richness per population averaged over loci, (2) Weir and Cockerham's inbreeding coefficient (F_{IS}), a global estimate of population differentiation (F_{ST}) with 95% confidence limits (Weir and Cockerham 1984), (3) population pairwise measures of F_{ST} with significance determined using permutation (10,000), and (4) tests for linkage disequilibrium between loci using a loglikelihood ratio test. The software MICRO-CHECKER ver. 2.2 (Van Oosterhout *et al.* 2004) was used to assess microsatellite loci for null alleles and scoring errors using formula 1 outlined by Brookfield (1996), as evidence of null homozygotes was not apparent. The sequential Bonferroni correction (Rice 1989) was used when performing multiple simultaneous comparisons.

Estimates of observed (H_O) and expected (H_E) heterozygosity were determined using the Excel Microsatellite Toolkit (Park 2001) and deviations from HWE were made using GENEPOP ver. 3.4 (Raymond and Rousset 1995). Mean allelic richness and observed heterozygosity were then compared among sample sites using a two-sided permutation test (10,000 permutations) also implemented in FSTAT. An analysis of molecular variance (AMOVA) was performed in GenAlEx using pairwise F_{ST} as the distance measure, with 10,000 permutations and missing data for loci set at 10%. Identical multi-locus genotypes were identified using the multi-locus matching tool also implemented in GenAlEx. The sequential Bonferroni procedure (Rice 1989) was used to adjust significance levels when performing multiple simultaneous comparisons.

A Discriminant Analysis of Principle Components (DAPC), implemented in the *adegenet* package for *R* (Jombart 2008; Jombart & Ahmed 2011) was used to summarize patterns of genetic differentiation between sample sites. Relationships between individuals at each site were estimated with the program ML-RELATE (Kalinowski *et al.* 2006). ML-RELATE calculates coefficients of relatedness (r) and putative relationships among individuals (*e.g.*, unrelated, siblings, parent/offspring) using a maximum likelihood approach.

The software package BOTTLENECK was also run to test for evidence of recent reductions in the effective population size based on a comparison of allele numbers and gene diversity at polymorphic loci (Cornuet and Luikart 1996). BOTTLENECK tests were performed on all remnants using the infinite allele model (IAM), stepwise mutation model (SMM) and the two-phased model of mutation (TPM), with the intermediate TPM considered most suitable for microsatellite loci (Cornuet and Luikart 1996). The variance for TPM was set to 30 % and the proportion of SMM in TPM set to 70%. Due to the relatively small number of loci, the Wilcoxon's signed-rank test was applied to determine significance based on 1,000 iterations (Cornuet and Luikart 1996). A qualitative descriptor of the allele frequency distribution ('mode-shift' indicator), which discriminates bottlenecked populations from stable populations, was also calculated in BOTTLENECK (Luikart *et al.* 1998). To account for multiple comparisons, we applied the FDR procedure (Benjamini & Hochberg 1995).

Rates of recent migration were estimated among each of the sampling locations using a Bayesian algorithm implemented in BAYESASS v.3.0.3 (Wilson and Rannala 2003), allowing migration among populations within the last three generations to be estimated. To identify movements among populations, five independent runs of 10^{-7} MCMC iterations were used following a burn-in period of 10^{-7} and a sampling interval of 500 steps. Chains were compared to a stationary posterior distribution for convergence by performing multiple runs with dispersed starting values. Proportion of individuals that were assigned as migrants (migration rates) and associated 95% confidence intervals (CIs) were estimated among each of the sampling locations.

Results

A total of 238 individual *B. marginata* samples from the 16 collection sites were successfully genotyped at 11 microsatellite loci (Tables 2 and 3). Marker independence was confirmed across all sample sites with linkage disequilibrium analyses indicating no significant linkage between loci, while MICRO-CHECKER analyses found no evidence of scoring errors or null alleles at any locus. A total of 120 alleles were detected (average 3.38 alleles per locus) over all sites (Table 3), and observed heterozygosity was moderate to high, ranging from 0.48 to 0.67 (mean $H_E = 0.56$). Estimates for BAL, BHO, BWN, ORR, PSU, SMC and WIL should be treated with caution due to a small sample size.

All sites were found to conform to HWE suggesting random mating (Table 3), except for sites KOA which showed significant deviations (*P* < 0.01). This estimate was influenced by a single locus only. Although significant inbreeding was not observed at any sample location, relatedness analyses revealed that a significant number of individuals at each collection sites are direct relatives, with an average of 16% of samples being half- or full-siblings, or parent/offspring. The lowest number of related individuals was recorded at BAL, BHO, ORR, and PSU (0%) and the highest at NYC and WTE (27%). As previously stated, estimates for BAL, BHO, BWN, ORR, PSU, SMC and WIL should be treated with caution due to the small sample size.

A global estimate of F_{ST} across all loci was significantly different from zero (F_{ST} = 0.169; 0.149 - 0.186 95% CI) indicating limited gene flow and genetic structuring between sampling sites. Pairwise population comparisons of F_{ST} showed weak, moderate and significant genetic differentiated between all site pairs (36 pairwise comparisons; Table 4). Sites with sample sizes >10 individuals were included in F_{ST} calculations to avoid biases of genetic structure. AMOVA analyses suggested a high level of genetic variation between sites (16%; *P* < 0.01). Results from the Bayesian migration analyses were highly congruent, which indicated limited migration among sites within the last three generations (Table 3). Estimates of the strength and directionality of migration indicate that each site has been largely dependent on recruitment from local sources, with minimal migration from non-local sources. Evidence of weak recent migration was recorded between three site pairs with each case being unidirectional and not exceeding 10% per generation (average 1.5% per generation). Collectively, these findings suggested a significant genetic structuring and limited gene flow among sites sampled across the central region of Victoria.

BOTTLENECK analyses detected recent reductions in the effective population size (bottleneck events) for all *B. marginata* remnants. The Wilcoxon's sign-rank test for heterozygote excess was significant after correction for multiple comparisons under the IAM and TPM models for most remnants, but significant excess was observed under all three models for remnants KAL and TRW only. These results were often supported by evidence of mode shifts, suggesting that many *B. marginata* remnants are not in mutation-drift equilibrium but rather have undergone significant reductions in effective population size in the recent past.

DAPC analyses retained 40 principal components, and the first two discriminant functions captured 95% of the total variance within the microsatellite dataset. When plotted, individuals from the WTE, MBK, LOP, HAV, NYC and KOA sites cluster distantly from all other sites which have overlapping centroids, (Figure 1a). These results suggest a significant genetic differentiation between several sites included in the analysis; however, the lack of discrimination

Table 3. Statistics for 16 *Banksia marginata* collection sites screened with 11 microsatellite loci. Relatedness = values representing the percentage of unrelated, half-sibling, full-sibling, and parent-offspring relationships (respectively) per site, with values in parentheses representing the total percentage of related individuals. Migration = the fraction of individuals in the population that are migrants derived from another population per generation (source population code provided). Mean values averaged across loci for number of alleles (*a*), expected (H_E) and observed (H_O) heterozygosity, Hardy–Weinberg equilibrium P-values (HWE), and inbreeding coefficients(F_{IS}). Statistical significance (α = 0.05) after correction for multiple comparisons is indicated by bold text.

Collection site	Code	n	Loci typed	Relatedness	Migration	α	HE	HO	HWE	FIS
Balborra	BAL	4	11	0	0%	2.73	0.5463	0.5227	0.99	0.048
Billy-Ho Nature Walk	BHO	6	11	0	0%	3.91	0.5895	0.6061	0.99	-0.031
Burke and Wills track north	BWN	7	11	86, 5, 10, 0 (14)	10%(BWS)	2.91	0.4535	0.5714	0.95	-0.288
Burke and Wills track south	BWS	12	11	92, 3, 3, 3 (8)	0%	3.55	0.4516	0.5592	0.90	-0.252
Havistock Hill	HAV	20	11	74, 7, 12, 7 (26)	0%	3.64	0.4568	0.5591	0.65	-0.231
Koala Park	KOA	14	11	67, 4, 26, 2 (33)	0%	2.73	0.4291	0.5639	**P<0.01**	-0.331
Long Point	LOP	30	11	75, 11, 6, 8 (25)	0%	4.00	0.5246	0.5758	0.02	-0.099
Mt Beckworth	MBK	17	11	82, 7, 9, 2 (18)	0%	4.27	0.6106	0.6738	0.01	-0.107
NYC	NYC	12	11	73, 14, 6, 8 (27)	0%	3.45	0.5171	0.5682	0.72	-0.104
Orr Street	ORR	4	11	0	0%	3.18	0.5682	0.6364	0.99	-0.143
Pastoria East	PSE	25	11	67, 13, 7, 13 (33)	0%	4.60	0.5500	0.4800	**P<0.01**	0.14
Petticoat Slatery Creek lower	PSL	17	11	80, 14, 4, 2 (20)	0%	3.91	0.5496	0.5384	0.10	0.021
Petticoat Slatery Creek lower	PSU	5	11	0	9%(PSL)	2.73	0.5253	0.5636	1.00	-0.083
Smeaton Cemetary	SMC	5	11	90, 0, 0, 10 (10)	0%	2.18	0.3715	0.4273	1.00	-0.173
Tooboorac	TOO	25	11	75, 13, 5, 7 (25)	0%	4.09	0.5749	0.5877	0.35	-0.023
Wilsons Rd, Kooroocheang	WIL	5	11	80, 0, 0, 20 (20)	5%(TOO)	2.36	0.4727	0.5636	0.99	-0.222
Whyte Rd, Kara Kara	WTE	30	11	73, 9, 6, 12 (27)	0%	3.27	0.5018	0.5758	0.72	-0.15

between several sites (which have been found to be genetically unique based on other independent analyses discussed above) could be due to recent population isolation and incipient early stages of genetic divergence. DAPC analyses were repeated to include sites from the Victorian Volcanic Plains (VVP) to provide insights into regional patterns in genetic differentiation. As before, DAPC analyses retained 40 principal components, with first two discriminant functions capturing approximately 95% of the total variance. When plotted, the sites from the central Victoria and the VVP separate across space (Figure 1b), which suggests that regional genetic differences might be driven by potentially limited historical and/or contemporary gene flow between regions.

Table 4. Pairwise estimates of F_{ST} between 9 *Banksia marginata* collection sites (sites with >10 individuals available for genetic analysis. Values shown in bold are non-significant (P > 0.001) and remained significant after corrections for multiple comparisons.

	BWS	HAV	KOA	LOP	MBK	NYC	PSL	TOO
BWS								
HAV	0.25							
KOA	0.23	0.24						
LOP	0.17	0.22	0.21					
MBK	0.16	0.16	0.17	0.16				
NYC	0.11	0.23	0.23	0.15	0.11			
PSL	0.14	0.17	0.09	0.13	0.09	0.10		
TOO	0.12	0.13	0.17	0.15	0.10	0.12	0.08	
WTE	0.24	0.21	0.24	0.18	0.14	0.21	0.13	0.13

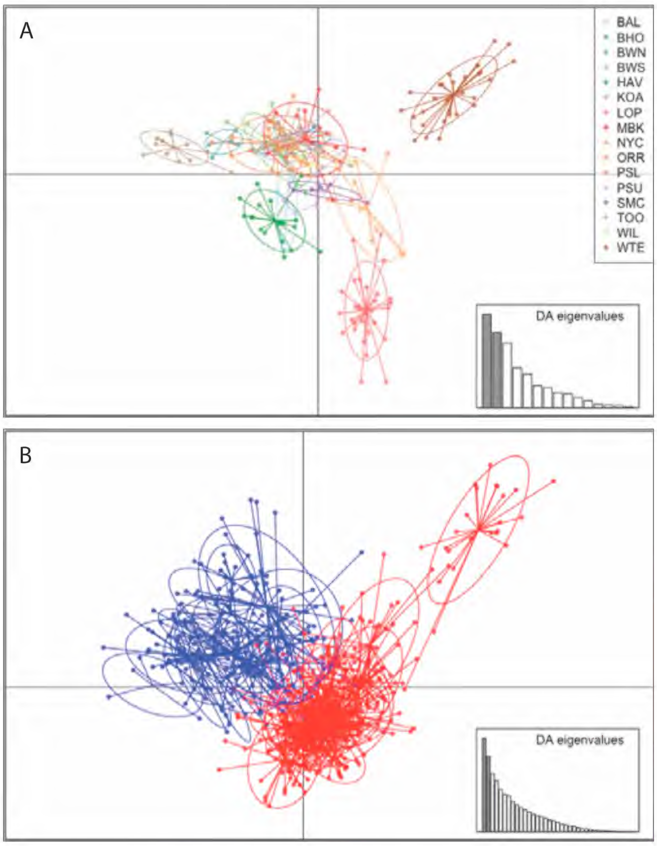


Figure 1. Discriminant Analysis of Principle Components; a. including individuals from all 16 *B. marginata* remnants from the central region of Victoria; b. individuals from all central region (red) and Victorian Volcanic Plains (blue) remnants.

Acknowledgements

Many people have made significant contributions to this study. Firstly, Bonnie Humphries (Connecting Country) initiated the project and coordinated the fund raising for the genetic study. Bonnie and Debra Saxon-Campbell (Kara Kara Conservation Management Network) coordinated the field collections along with colleagues from local landcare, community and government groups. The Australian Network for Plant Conservation assisted in the hosting of a public forum in Harcourt in March, 2018 where results from this study were presented to the general public (funded by the Norman Wettenhall Foundation). Finally, we thank Linda Broadhurst (CSIRO) and Susan Hobee (LaTrobe University) for their support with genetic analyses and drafting of the report content.

References

Benjamini, Y. and Hochberg, Y. (1995). Controlling the false discovery rate – a practical and powerful approach to multiple testing. *Journal of the Royal Statistical* Society*:* Series B *(Statistical* Methodology*)* 57: 289–300.

Brookfield, J.F.Y. (1996). A simple new method for estimating null allele frequency from heterozygote deficiency. *Molecular Ecology* 5: 453–455.

Cornuet, J.M. and Luikart, G. (1996). Description and power analysis of two tests for detecting recent population bottlenecks from allele frequency data. *Genetics* 144: 2001–2014.

Goudet, J. (1995). Fstat (version 1.2): A computer program to calculate F-statistics. *Journal of Heredity* 86: 485–486.

Jombart, T. (2008). *adegenet*: a R package for the multivariate analysis of genetic markers. *Bioinformatics* 24: 1403–1405.

Jombart, T. and Ahmed, I. (2011) adegenet 1.3-1: new tools for the analysis of genome-wide SNP data. *Bioinformatics*. 27: 3070–3071

Kalinowski, S.T., Wagner, A.P. and Taper, M.L. (2006). ML-Relate: a computer program for maximum likelihood estimation of relatedness and relationship. *Molecular Ecol Notes*. 6: 576-579.

Luikart, G., Allendorf, F.W., Cornuet, J.M. and Sherwin, W.B. (1998). Distortion of allele frequency distributions provides a test for recent population bottlenecks. *Journal of Heredity* 89: 238–247.

Park, S.D.E. (2001). *Trypanotolerance in West African cattle and the population genetic effects of selection*. PhD Thesis. University of Dublin, Dublin.

Peakall, R. and Smouse, P.E. (2006). Genalex 6: Genetic analysis in excel. Population genetics software for teaching and research. *Molecular Ecology Notes* 6: 288–295.

Raymond, M. and Rousset, F. (1995). An exact test for population differentiation. *Evolution* 49: 1280–1283.

Rice, W.R. (1989). Analyzing tables of statistical tests. *Evolution* 43, 223–225.

Van Oosterhout, C., Hutchinson, W.F., Wills, D.P.M. and Shipley, P. (2004). MICRO-CHECKER: software for identifying and correcting genotyping. *Molecular Ecology Notes* 4: 535-538.

Weir, B. and Cockerham, C. (1984). Estimating F-statistics for the analysis of population structure. *Evolution* 38: 1358–1370.

Wilson, G.A. and Rannala, B. (2003). Bayesian inference of recent migration rates using multilocus genotypes. *Genetics*. 163: 1177–1191.

ANPC member profile

David Coates

What is your current position?

I am a Research Associate and was, until recently, a Senior Principal Research Scientist and Program Leader, Plant Science and Herbarium Program, in the Western Australian Department of Biodiversity, Conservation and Attractions.

What projects are you working on at the moment?

I am currently involved in a range of research and conservation projects covering threatened plant species, restoration genetics and ecological restoration, and evolutionary biology. There are two projects that are a key focus at the moment. The first is part of the National Environmental Science Programme's Threatened Species Recovery Hub and is investigating approaches for improving threatened plant translocation success and species recovery. Major outcomes have been the publication of the third addition of the Guidelines for the Translocation of Threatened Plants in Australia, the establishment of an Australian plant translocation database and the preparation of a paper reviewing plant translocations in Australia. The second project 'Is restoration working? An ecological genetic assessment' is funded by the Australian Research Council through the University of Western Australia and is investigating the ecological and genetic success of recent restoration activities carried out as part of the Gondwana Link initiative in south west Western Australia.

How did you end up working in plant conservation?

Following my undergraduate degree at the University of Western Australia I moved into the fields of genetics, evolutionary biology and botany, working through Honours and then a PhD on chromosome variation and patterns of speciation in triggerplants (*Stylidium*), a fascinating group that has undergone explosive speciation in the southwest. This work set me moving into plant conservation with a number of field trips through southwest Western Australia highlighting the remarkable richness of the flora and many issues associated with habitat loss and vegetation change.

I moved back to Western Australia in 1985, from Canberra, following a postdoctoral position at the Australian National University, taking up a research position in conservation genetics and plant biology in the newly established Department of Conservation and Land Management. This was the start of not only a great challenge but also a hugely rewarding part of my career working on the conservation of the Western Australian flora. This also started my long involvement with threatened plant species management and a series of initiatives aimed at improving their conservation.

Dave Coates. Photo: Nathan Emery

What is your favourite plant and why?

My favourite plant is the trigger plan *Stylidium crossocephalum* (the posy triggerplant), a species with extensive intra-specific chromosome variation I studied as part of my PhD and continue to research.

Why do you think the ANPC network is important and what do you see as our priorities?

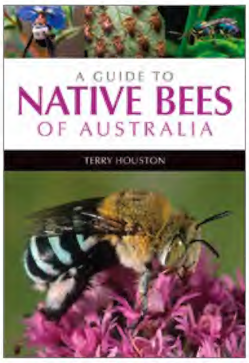
My close association with the ANPC has repeatedly reinforced my view that to achieve lasting outcomes in plant conservation public support through citizen science projects and community groups is essential. I believe the ANPC has a unique capacity to galvanize that public support. Since its inception the ANPC has been a major player in plant conservation and has made key contributions to ecological restoration initiatives and improved threatened plant recovery in Australia. The recent launch of the third addition of the Guidelines for the Translocation of Threatened Plants in Australia is a clear example of the ANPC's ability to deliver key initiatives in plant conservation.

I believe, more than ever, that the ANPC can continue to lead the facilitation and communication of plant conservation throughout Australia. There is ongoing community interest and support for plant conservation and this is reflected in the continued participation of land managers, government departments, industry, the volunteer conservation movement and the broader community in ANPC workshops and conferences, the requests we get from other organisations and government to participate in, and comment on, various flora conservation related activities and initiatives.

Book review

A Guide to Native Bees of Australia

Terry Houston, 2018. CSIRO Publishing, Clayton South. 272 pp. ISBN: 9781486304066. RRP $49.99



Dr Houston has produced a superb and timely addition to the literature concerning bees and provides a wealth of information to stimulate the bee enthusiast and beekeeper alike. Enriched by some of the finest and most impressive macrophotographs and photomicrographs of bees and their anatomy taken by a cohort of talented photographers, this book offers a fascinating insight into many of the species that comprise Australia’s native bee genera and five families. Dr. Houston’s passion, years of experience and knowledge are evidently embodied throughout the text, and his succinct writing style makes the field of entomology and technical language of bees accessible to the non-specialist. Even so, specialists too will be delighted with the content and level of detail, supported by further reading advice and a lengthy bibliography of key resources.

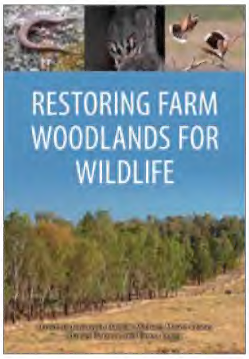
Laden with scientific and entomological facts, the reader is taken deep into the captivating world of bees and their relationships with the environment. The physical characteristics and appearances, behavioural patterns, societal natures, nesting habits, threats and even curiosities are detailed across a series of well-written and well-structured short chapters divided into two parts: (1) Overview of bees and their biology, and (2) Identification of bees. The first part covers a variety of topics and sets the basis for understanding native bees whilst the second part constitutes a significant portion of the book and offers a close examination of the five bee families. Throughout the second part the reader is provided with substantial detail on key identifying features of bee species.

With increasing social awareness occurring within Australia and globally of both the importance and plight of bees, this guide will surely have the reader in awe spending much of their time outdoors and engaged in nature, eagerly seeking out and observing the native bees that might be in their area. Perhaps the reader will even find themselves fashioning ‘bee hotels’ or introducing specific floral species to their gardens following some of the useful tips provided at the end of Part 1 to encourage some of our country’s wonderful native bee colonies to their area and to nest, thrive, and be enjoyed.

Reviewer: Paul Kucera, beekeeper, Melbourne

Restoring Farm Woodlands for Wildlife

David Lindenmayer, Damian Michael, Mason Crane, Daniel Florance and Emma Burns
Pub. CSIRO, Locked Bag 10, Clayton South, Victoria, 3169 (2018). ISBN 978-1-4863-0964-1. Paperback, 122 pp. RRP $39.99



Restoration of some form of native vegetation in previously cleared landscapes is a growing (pardon the pun) activity throughout the agricultural zones of Australia. Landcare groups and other private groups and individuals are active in tree planting, weed removal, fencing and all the other activities that are part of this campaign in habitat restoration. There is a need for a text that brings together and summarises in an accessible way what we’ve learnt so far about how to revegetate most effectively.

This book is logically organised, starting with a statement of the current situation (the ‘problem’) and then providing the background of the authors – their credentials as writers in this intellectual space, the sources of their expertise and the assumptions and limitations that govern the book. This book is an outcome of decades of research and records encompassing many properties in south-eastern Australia. Unfortunately, the book’s bias towards the authors’ research and survey efforts shows through early on, even in the Acknowledgements (with appreciation shown for the ‘ … *generous funders of* ***our*** *work over the past two decades,* my emphasis). This bias pervades the book. All the authors are (or were) members of a tight research group based at the Australian National University in Canberra. Other contributors to the field are not completely ignored. There are occasional references to the work of others. Nevertheless, the authors’ work dominates the book.

Regardless of this bias, the authors and their research group are principal players in this increasingly important space of native vegetation restoration in agricultural landscapes and their collective experience is valuable.

The authors are careful to explain aspects of revegetation that are to be discussed and, refreshingly, aspects that they will not cover here. The text is clearly oriented towards the concerned public, including landholders. Scientific data are presented in a decidedly accessible form. Call-out boxes are very successfully used to explain more esoteric scientific points or social issues outside the sequential logic of the rest of the text. For example, Box 1.3 provides one of the best, simplest and briefest explanations the reviewer has read of the peer review process that underpins the scientific method. Box 1.5 clarifies issues not covered by this book (an important qualifier, often otherwise overlooked). Box 2.4 thoroughly immerses the book in the practical landscape and practicable revegetation, not in some unattainable ideal.

The relevant component topics are covered, from what, where and how to plant, through management, changes with time, creating a whole-farm plan and monitoring. The authors are careful to provide neither formulae nor schema that purport to direct the best revegetation efforts. Again and again, the reader is reminded that local circumstances may be unusual or even unique, such that all revegetation plans must be adapted to local conditions and histories. This pervasive theme underscores the authors' determination to write a practical manual, not a series of theoretical tenets that are difficult for the practitioner to put into effect. This lack of a 'best practice' formula is somewhat frustrating, but is sensible and realistic. Useful guiding principles for revegetation are outlined and one of the most useful aspects of the book is that it helps focus the practitioners' on long-term outcomes and real (measurable) achievements.

Weed control is not ignored in the book. But it is clear that the authors have most experience where weeds are not a major handicap to revegetation. In some landscapes, notably on the more fertile geologies (particularly basalt) or landforms (such as river flats and drainage lines), weeds have captured the landscape so tightly that extensive and intensive weed removal works are a pre-requisite for revegetation. Dominance by perennial weeds (such as the thistles *Cynara* and *Silybum*, or grasses, *e.g.*, *Nassella* and *Phalaris* species) may necessitate intensive weed control before any further revegetation works. This issue is barely covered, and inadequately, in this book.

There is a gratifyingly small number of errors (*e.g.*, p.41 – 'Larger areas supporting more species' is not a summary definition of the Species-Area curve, and p.79, Box 6.3 – Australian trees are not 'notoriously bad at extracting nutrients from the already nutrient poor soil'. Indeed, some Australian trees are justifiably renowned for being able to extract otherwise limiting nutrients from almost nutrient-free soil, *e.g.*, species of *Banksia* and *Allocasuarina*. Ecto-mycorrhizae are widespread on tree species around the globe and should not be seen as separate from the trees with which they're associated.

In summary, the book is a useful and worthy addition to the shelves of any land management organisation and all landholders concerned with revegetation in agricultural landscapes. It's an accessible summary of much recent research and a useful statement of guiding principles that all successful revegetation works should keep in mind. It's recommended.

Reviewer: David Cheal, Hon. Research Fellow
Centre for Environmental Management, Federation University, PO Box 663, Ballarat VIC 3353
d.cheal@federation.edu.au

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News

12th Australasian Plant Conservation Conference held 11–15 November 2018

Thank you to all the presenters, attendees and sponsors for making the APCC12 conference such a success. Most of the presentation PDFs are gradually being added to the conference website here http://anpc.asn.au/APCC12/presentations to share with conference participants and the wider plant conservation community. View the Flickr photos of the conference here https://www.flickr.com/photos/anpc/sets/72157698268724690. Also, go to the ANPC's Twitter page at https://twitter.com/ANPlantC to see more photos from the week and read the conference commentary.

APCC12 Field Trip 1 participants at Pomaderris Nature Reserve to inspect *Pomaderris delicata* translocations. Photo: Libby Lindsay

ANPC's Translocation Guidelines launched!

Threatened Species Commissioner, Dr Sally Box, launched the 3rd edition of the ANPC's *Guidelines for the Translocation of Threatened Plants in Australia* at the APCC12 Welcome Reception on 11 November 2018. Watch the launch videos here:
Dr Sally Box https://app.wipster.io/Review/CcHpFgAyeU89XmqmCCXbjmO7eilSQ8_vnB41-DwGgPLW6Bpr7w#timecode=0m3s0f
Prof Brendan Wintle https://app.wipster.io/Review/CcDpFgDX6dKMqSbeJZ49Wqi7WcwA5AvJCfSu0hjBCvSvVbhfCQ#timecode=7m8s12f
Dr Judy West https://app.wipster.io/Review/CcvpFgADnuLSta6nlgSP0UL6V_qvxlqvhWASoXIlhg4-5Vsk3Q

The ANPC would like to thank the Threatened Species Recovery Hub for funding this revised edition, the ACT Environment, Planning and Sustainable Development Directorate for the printing, project manager Lucy Commander and all the expert authors and steering committee members. With input from over 30 experts across the country, 23 new case studies, all new colour photographs illustrating translocation techniques and updated references, the Guidelines are essential reading for all those involved in translocation projects. They provide step-by-step information on how to do best-practice translocations, improve translocation success and contribute to preventing plant extinctions. Purchase your copy of the guidelines at **http://anpc.asn.au/translocation**

TRANSLOCATION GUIDELINES
Guidelines for the Translocation of Threatened Plants in Australia – Third Edition

Dr Sally Box launching the 3rd edition of the ANPC's Translocation Guidelines. Photo: Jo Lynch

Plant translocation: New guidelines a game changer

Translocation is a very important tool in the fight against plant extinctions. Knowing when to do translocations, how to do them and how to measure their success can be a complicated business, especially considering the huge range of threatened plants in Australia. So where do you find the answers? Luckily, they are now all in one place, in new guidelines that will be a game changer for plant translocation. Dr Lucy Commander lets us know what is on offer **http://www.nespthreatenedspecies.edu.au/news/plant-translocation-new-guidelines-a-game-changer**

Leonie Monks, Rebecca Dillon and Sarah Barrett collecting seeds from a *Lambertia orbifolia* translocation. Photo: David Coates

Myrtle Rust draft Action Plan and review document are now available

Two recent (June 2018) documents have been uploaded to the Myrtle Rust information hub on the ANPC website, by permission of the Australian Plant Biosecurity Science Foundation:
1/ *Myrtle Rust reviewed: the impacts of the invasive pathogen* Austropuccinia psidii *on the Australian environment.* Makinson, R.O. (2018a). Plant Biosecurity Cooperative Research Centre, Canberra.
2/ *Myrtle Rust in Australia – a draft Action Plan.* Makinson, R.O. (2018b). Plant Biosecurity Cooperative Research Centre, Canberra.
Myrtle Rust is a major new threat to Australia's flora. This information hub has been developed by the ANPC to contribute to response capabilities here in Australia and overseas. The ANPC has been at the centre of attempts by concerned scientists and conservation practitioners to develop a coordinated and funded national response to this threat. **http://anpc.asn.au/myrtle-rust**

Myrtle Rust reviewed

The impacts of the invasive plant pathogen *Austropuccinia psidii* on the Australian environment

R. O. Makinson 2018

Australian Government

National Environmental Science Programme

CRC PLANTbiosecurity

Saving the Threatened Audas Spider-orchid (*Caladenia audasii*) from Extinction

The ANPC is working with the Royal Botanic Gardens Victoria (RBGV), Friends of Grampians Gariwerd and the Australasian Native Orchid Society (Victoria Group) Inc. on this exciting project. Approximately 50 endangered *Caladenia audasii* seedlings are now growing at the Orchid Conservation shadehouse thanks to our Victorian Government Biodiversity On-ground Action grant. More seed was sown in Spring 2018. They will be reintroduced back into their native habitat in 2020. Pollinator baiting is currently underway. There are only 5 known plants left in the wild! **http://anpc.asn.au/audas_spider-orchid**

C. audasii **seedlings growing at the RBGV Orchid Conservation shadehouse. Photo: Noushka Reiter**

The ANPC 2019 Calendar is now available!

The 2019 ANPC calendar features 12 threatened plants from the ACT region promoted by the 12th Australasian Plant Conservation Conference to highlight some of the many endangered plants in and around the territory. All but one are listed as vulnerable, endangered or critically endangered at the national level. The profits from the sale of this calendar will be directed towards ANPC projects aiming to raise community awareness of threatened plant species and endangered ecological communities throughout Australia. $15 each (+ postage and handling) and only $10 for ANPC members! Order the calendar here **http://anpc.asn.au/calendar**

Cuttings: Plant news from around Australia

Drovers say Australia's legendary outback stock routes in danger of collapse

Australia's iconic stock routes are languishing after years of neglect and are in danger of being privatised, drovers and ecologists warn. The historic network of reserves for travelling sheep and cattle are etched into the national psyche by writers Henry Lawson and Banjo Paterson. They're also a refuge for endangered flora and fauna, and are rich in Indigenous heritage. 'We should be managing them like the Royal Botanic Garden'...Ecologist Phil Spark is deeply concerned about areas of the routes being fenced off by landholders, with permits to graze for one month or up to five years. ‘We are losing a lot of diversity in plants through more constant grazing. Vast areas, really large areas are now fenced for long-term grazing permits,’ he said. He has just finished an ecological assessment of the north-west region, and said it identified 60 threatened species of plants and animals. **http://www.abc.net.au/news/2018-06-30/drovers-say-australian-outback-cattle-routes-in-peril/9916168**

Culling dingoes start of 'domino effect' that may be changing the shape of Australia's landscape

In essence, the researchers believe that by removing small omnivorous animals like the spinifex-hopping mouse, shrubs have been able to grow in much greater abundance. More shrubs have led to more shade, which allows heat-sensitive plant species, as well as lichens and mosses to survive in the low undergrowth. This increased vegetation has heightened the structural integrity of the dunes, and altered the way the wind flows and shifts sand across the landscape. The result, according to the researchers, is higher and more varied dunes on the side of the fence where dingoes are excluded. **http://www.abc.net.au/news/science/2018-07-07/culling-dingoes-changes-landscape/9938286**

The largest floral show on earth happens on the ground in Western Australia

One of the world’s great natural wonders awaits, the largest floral show on earth. Western Australia’s wildflower collection is the world’s largest with more than 12,000 species and 60 per cent found nowhere else. ‘They colour the landscapes from coast to forest and city to outback,’ say our tourism tsars. The six-month flowering season begins in the north in June and July on the vast outback plains of the Pilbara, Goldfields and Coral Coast where vibrant blooms contrast with pindan earth, rugged canyons and turquoise sea. By September, it has moved south and reached Perth’s botanical gardens, nature reserves and national parks, finishing with a flurry in October and November throughout the forests and coastal heaths of the south west. **https://www.haveagonews.com.au/travel/on-your-doorstep/the-largest-floral-show-on-earth-happens-on-the-ground-in-western-australia/**

NSW Environment Office applies drone AI to buzz endangered plants

In a move that reflects the increasing use of unmanned aerial vehicles by government agencies, councils, utilities and surveyors to glean data and imagery of assets more accurately and affordably, OEH is using the technology to identify endangered and invasive plant species. An OEH spokesperson told iTnews that ‘scanning and surveying large areas of bushland in the hope of spotting a threatened species usually involves field trips or the chartering of a helicopter to access the area and capture images,’ which is both costly and time intensive. However a recent pilot program in partnership with Fujitsu’s Digital Owl project has already yielded success by identifying two endangered plant species in the state’s Upper Hunter region. **https://www.itnews.com.au/news/nsw-environment-office-applies-drone-ai-to-buzz-endangered-plants-498490**

The plan to save one of Australia's rarest plants

Only four are known to exist in the wild, making the *Banksia vincentia* one of Australia's rarest plants. But conservationists in Canberra and on the NSW South Coast hope its critically endangered status will soon be a thing of the past as they work to drastically boost the flowering plant's numbers and secure its future. The species is only found in the wild near the small South Coast town of Vincentia, but new seed orchards are now being constructed to protect and propagate the plants at Booderee National Park at Jervis Bay and the Australian National Botanic Gardens in Canberra. **https://www.canberratimes.com.au/national/act/the-plan-to-save-one-of-australia-s-rarest-plants-20180724-p4zt8d.html**

Protecting our mountain giants

Australia is losing large old hollow-bearing trees in our mountain ash forests due to logging, fires and climate change. A team at the Australian National University have been investigating the importance of these trees, the implications of their loss and things we can do to ensure we have enough mountain giants for the future. Large old trees are keystone structures in many of the world's forests. Despite being of great ecological importance and fulfilling critical roles in these forest ecosystems, globally, large old trees are in decline. In the mountain ash forests of south-eastern Australia, the loss of large old trees has been rapid and is ongoing, with the average forest age now younger than it has ever been. This changes the fundamental dynamics of the forest, as young forest is more fire-prone, stores less carbon and has less water runoff. **http://www.nespthreatenedspecies.edu.au/news/protecting-our-mountain-giants**

Funding to monitor rare Curly-bark Wattle at Lake Cargelligo

The Office of Environment and Heritage (OEH) will take advantage of the Curly-bark Wattle's brief flowering season from August to September to find and monitor this rare plant. The NSW Saving our Species (SoS) program had provided $3,200 in funding to undertake fieldwork monitoring of the wattle on Monia Gap Station, west of Lake Cargelligo. 'Only about 30 populations of this wattle are known and most of these are very small, located near Cobar south to Hillston area,' said OEH Senior Threatened Species Officer, Darren Shelly. Populations of the Curly-bark Wattle occur in conservation areas in Gundabooka National Park near Bourke, and Yathong and Round Hill Nature Reserves. About 20 of the populations have fewer than 500 individual plants left. **https://www.environment.nsw.gov.au/news/funding-to-monitor-rare-curly-bark-wattle-at-lake-cargelligo**

Singing the spiny daisy back to life

They say it's good to talk to your plants to help them grow. Well students from the Waikerie Primary School in South Australia's Riverland are taking it one step further – they're singing nursery rhymes to the six little plants in their care. They're spiny daisy plants, a critically endangered species found in South Australia's mid-north. The plant, first recorded on the ill-fated Burke and Wills Expedition in the 1860s, was thought to be extinct until it was found by chance growing on the side of the road in 1999. Since then a concerted effort has been underway to propagate the plant to ensure its survival. Listen here **http://www.abc.net.au/news/rural/2018-08-04/singing-the-spiny-daisy-back-to-life/10060534**

ANPC Note: Banrock Station, ANPC member and APCC12 sponsor, planted 360 Spiny Daisies (*Acanthocladium dockeri*) in 2014 and now have around 4,500 growing in their wetland conservation area. They donated plants to Waikerie Primary School as part of a larger translocation project to help secure its future.

Brisbane Seed Bank storing some of the world's rarest seeds for posterity

A small vault in the back of the Brisbane Botanical Gardens is under lock and key, keeping some of the world's rarest seeds safe and sound. The Brisbane Seed Bank began its collection in 1983 and now holds more than 1,000 species of seeds. One of most valued is the Senna species (Davies Creek), a flowering tropical shrub found only on the Atherton Tablelands in far north Queensland. 'It's never been recorded before, so this could be the only collection of seeds in the world of this very special plant,' curator Dale Arvidsson said. 'We can't say just how rare this plant is, but when we collected these seeds there was only three plants producing them.' **http://www.abc.net.au/news/2018-08-05/the-rare-australian-seeds-stored-in-brisbanes-seed-bank/10066678**

Scientists race to bank seeds before rainforests die

Why is one nut different from another? Why does the palm-sized seed of the hairy walnut hate being dried, making it a tough nut to preserve? How can the macadamia withstand being frozen at minus 192 degrees celsius, and still revive to produce new seedlings – as new research discovered a few weeks ago – but other oily nuts won't survive in these conditions? Far from questions leading to a punchline, these are the challenges facing scientists at the Royal Botanic Gardens in Sydney and Mt Annan who are racing to develop effective ways of preserving seeds from rainforest plants (like the macadamia) before they become extinct. **https://www.theage.com.au/environment/conservation/scientists-race-to-bank-seeds-before-rainforests-die-20180809-p4zwl6.html**

A burning issue: Forest fires make more fires

The most comprehensive analysis ever performed of fires in the Australian Alps has revealed that fire has made the forests more likely to burn. Frequent fire increases the risk of fire and of ecosystem collapse in mountain forests, which are highly vulnerable to climate change. ‘My research contradicts one of the central assumptions in Australian fire management – that forest simply accumulates fuel over time and becomes increasingly flammable,’ says Dr Philip Zylstra, a research fellow from the University of Wollongong. ‘Fires in the Australian Alps National Parks have been smaller and less severe in long-unburnt forests. This finding applies regardless of forest type in the Alps. The fire season is lengthening and becoming more severe in Australia, in line with global trends. With an increase in lightning activity, this has the potential to greatly increase the impact of fire on forests and other ecosystems.’
https://www.ecolsoc.org.au/burning-issue-forest-fires-make-more-fires

Global Partnership for Plant Conservation Conference held in South Africa 28-30 August

The Global Strategy for Plant Conservation was first adopted in 2002 as a program of work under the Convention on Biological Diversity. The strategy recognises that our survival is intrinsically linked to plants and aims to halt the loss of plant diversity through 16 plant conservation targets. International collaborations contribute significantly to countries’ ability to meet these targets and Australia plays an important role.
In the last week of August, the South African National Biodiversity Institute, in association with the Secretariat of the Convention, hosted the Global Partnership for Plant Conservation Conference and 6th Liaison Group meeting at Kirstenbosch National Botanic Gardens in Cape Town, South Africa. The conference welcomed 125 delegates from more than 30 countries. Damian Wrigley from the Australian Seed Bank Partnership presented on Australia’s contribution to Targets 8 and 9 through ex situ seed conservation, and represented Australia at the 6th Liaison Group meeting. The conference and meeting evaluated global progress towards the targets of the Global Strategy. Deliberations from both the conference and the 6th Liaison Group meeting will be presented at CoP14 in Egypt later this year, where Australia will report our progress towards the targets as part of our 6th National Report to the Convention.
https://www.sanbi.org/event/global-partnership-for-plant-conservation-conference

Black Mountain Symposium background papers now available

The Black Mountain Symposium was held 24–25 August 2018 at CSIRO Canberra where many biophysical and cultural papers were presented including 'Vascular plants of Black Mountain, 1969-2017' by Rosemary Purdie which provides a benchmark for tracking changes in floristic diversity over future decades, and 'Vegetation types and vegetation dynamics on Black Mountain' by Michael Doherty. In 'Rare plants on Black Mountain Sandstone' Michael Mulvaney discusses the 2013 listing of 317 plant species in the ACT due to their suspected rare or uncommon occurrence there. Since then much survey, record checking and use of citizen science has documented the abundance and distribution of these plants in the territory. As a result of this new information, some plants were taken off the list while others were added. Download the papers here.
https://www.friendsofblackmountain.org.au/SymposiumPapers

Rare wild orchids thrive despite harsh, dry winter in Western Australia

In the midst of what many farmers are calling the driest winter ever experienced on Western Australia's south coast, fragile native orchids are still going strong. The striking Queen of Sheba orchids are popping up in droves, while hardy species such as grasstrees and banksias are dying off in sections of bushland near the coastal town of Bremer Bay. Orchid lover and explorer Terry Dunham has been keeping an eye on the number of orchid species growing at confidential sites across the Great Southern region. ‘They appear very delicate, but orchids are extremely resilient,’ he said. ‘They have a tuber root system that grows deep into the ground so during a dryer season they may start later but they have a good energy source. Once the days get longer and warmer they will power away.’
http://www.abc.net.au/news/2018-07-26/rare-orchids-thrive-despite-wa-dry-winter/10035362

Native plant may hold key to developing potential treatment for dengue virus, researchers say

Queensland researchers say a native Australian plant which ‘grows all over the place’ may hold the key to developing a potential treatment for dengue virus. There is no cure or vaccine for the mosquito-borne virus which infects 390 million people a year. Scientists from the Queensland University of Technology (QUT) have conducted tests on monkey cells and found the plant, identified only as Species 8473 for commercial reasons, killed all four strains of the dengue virus.
http://www.abc.net.au/news/2018-07-29/native-australian-plant-kills-dengue-virus/10043820

What wattle is that? A new app holds the answer

As part of National Wattle Day celebrations, Director of National Parks Dr Judy West launched the new Wattle: Acacias of Australia app which helps users identify over 1070 species of wattle. ‘Our native flora forms part of our Australian identity. May Gibbs famous children’s books are infused with it, our national sporting teams’ colours are inspired by it, and today, we have a national celebration dedicated to our nation’s floral emblem,’ Dr West said. Download the app here
http://www.environment.gov.au/mediarelease/what-wattle-new-app-holds-answer

Don’t forget about Australia’s threatened plants

Often fluffy and cute, Australia’s threatened animals enjoy a much higher profile than the country’s threatened plants, despite that they’re the backbone of all life on earth. We have deserts, wetlands, rainforests – tropical and temperate – alpine regions and shrublands, all containing unique, highly adaptive flora, with many species unchanged over millions of years. After almost two centuries of European settlement the biodiversity of Australia, however, has faced a number of challenges – most importantly huge losses of habitat resulting in fragmented ecosystems and a lack of connectivity, and the introduction of invasive species such as rabbits and goats, which eat or trample our flora. According to Seedbank Manager at the Australian PlantBank, Peter Cuneo, around 37 species of plant have gone extinct in this time, meaning that, compared to other countries, we’d be considered ‘middle of the pack’ when it comes to our plant extinction rate, just behind the United States, south-east Asia, South America and Madagascar, he says.
https://www.australiangeographic.com.au/topics/science-environment/2018/09/dont-forget-about-australias-threatened-plants/

Why are there so many fires burning the Top End black every year?

A blazing fire lines a highway as the air fills with the sweet and heady scent of the bush. Overhead, kites soar and swoop. Smoky clouds rise above the savannah, and at sunset the sky turns a deep neon orange. It's an all-too-familiar sight in the Northern Territory and a sure sign that the dry season has arrived. But why are there so many fires burning and what are they doing to the environment?
http://www.abc.net.au/news/2018-09-18/why-are-there-so-many-fires-burning-the-top-end-black-every-year/10238998

How fire could unlock suburbia's 'hidden treasure' of wildflowers

Michael Slot was on his hands and knees in a suburban park in Melbourne’s north-eastern outskirts when he came across a plant he didn’t recognise. The broad-leaf early nancy (*Wurmbea latifolia* subsp. *vanessae*) was found in a Mill Park park two years ago and is now a reoccurring feature late winter and early spring. It was small, white and – as far as wildflowers go – relatively nondescript. But the discovery was so exhilarating that Mr Slot, an indigenous vegetation management officer with Citywide, still gets ‘jacked up with adrenaline’ just talking about it. The flowering lily was thought lost to the area, and had not been found so close to the city in more than 120 years.
https://www.theage.com.au/environment/conservation/how-fire-could-unlock-suburbia-s-hidden-treasure-of-wildflowers-20180921-p5059v.html

Budj Bim aerial seed bombing could see return of the tiger quoll

The ancient Aboriginal settlement that is today's Budj Bim National Park has made a significant recovery in recent years, but it still bears some of the scars caused by decades of western farming and neglect. Greening Australia has taken to the skies in an effort to repopulate the park's dwindling manna gum population that was destroyed by farming and a wild fire that tore through the area 12 years ago. The national organisation is aerially seeding 400 hectares of rough, volcanic surrounds in what's believed to be the largest project of its type in Australia.
http://www.abc.net.au/news/2018-09-23/aerial-seeding-budj-bim-world-heritage/10289682

Climate change kills Antarctica's ancient moss beds

Emerging from the ice for a brief growing season every Antarctic summer, the lush green mosses of East Antarctica are finally succumbing to climate change. That is according to a study of the small, ancient and hardy plants - carried out over more than a decade. This revealed that vegetation in East Antarctica is changing rapidly in response to a drying climate. 'Visiting Antarctica, you expect to see icy, white landscapes,' said lead scientist Prof Sharon Robinson from the University of Wollongong, in Australia. 'But in some areas there are lush, green moss beds that emerge from under the snow for a growing period of maybe six weeks.'
https://www.bbc.com/news/science-environment-45629395

Cultural burn offs to save the animals at the wetlands

ACT Parks and Conservation are using a tens-of-thousands year old method to help Canberra's native animals and plants and it's relatively simple. Aboriginal fire project officer Dean Freeman's technique means taking one match to a clump of exotic grass and letting it burn. Mr Freeman said it destroyed the introduced grasses which prevent native animals from nesting thereby avoiding the use of toxic herbicides, it reduces the fuel load over bushfire season and allows native grasses to shoot back.
https://www.canberratimes.com.au/canberra-news/cultural-burn-offs-to-save-the-animals-at-the-wetlands-20180926-p5064c.html

Restoring the endangered Yass Daisy

Land clearing has resulted in the loss of approximately 85 per cent of the Box Gum Woodland vegetation community, and what remains is often highly degraded. The woodlands are important to a number of threatened ground cover species including the Yass Daisy. A new project is addressing the problem of how to best conserve this critically endangered vegetation community. The project will run as an adaptive management experiment trialling and testing techniques while restoring ground cover species within threatened Box Gum Grassy Woodlands. The research team will collaborate with key partners to develop best practice methods for propagating threatened plants off-site, and then reintroduce them into appropriate habitat, including on private property.
http://www.nespthreatenedspecies.edu.au/projects/restoring-the-endangered-yass-daisy

Will our beloved waratahs survive climate change?

NSW's floral emblem, the waratah (*Telopea speciosissima*), has a new career in climate change research.
In greenhouses and the field, waratahs are helping scientists foresee the future. When fed extra carbon dioxide in one experiment, young waratahs thrived. This was expected because carbon dioxide is plant fuel, which means many plants should benefit from a high carbon world, unless it brings worse droughts, which it may. When subjected to high temperatures, waratahs from around Sydney outgrew those from the Blue Mountains.
https://www.australiangeographic.com.au/blogs/wild-journey/2018/03/will-our-beloved-waratahs-survive-climate-change/

When Jamie fell in love with the mountains

Distinguished Professor Jamie Kirkpatrick has been crawling across lawns for more than 70 years, it's just that this one is on the top of a mountain and is full of plants from the cretaceous. It's an incredibly rare vegetation type, only found in small islands on the top of Tasmania's peaks, and it's one of the reasons that Jamie fell in love with the mountains. For over 40 years, the geographer has spent time mapping Tasmania's vegetation, aiming to provide the best data possible so that biodiversity might be preserved. Download audio here
https://www.abc.net.au/radionational/programs/offtrack/jamie-kirkpatrick-alpine-vegetation/9879840

Leek orchids are beautiful, endangered and we have no idea how to grow them

Leek orchids don't have many friends. Maybe it's because they lack the drop-dead gorgeous looks of many of their fellow family members. Or perhaps it's because they're always the first to leave the party: as soon as sheep or weeds encroach on their territory, they're out of there. Whatever the reason, you don't see leek orchids around very often.
https://theconversation.com/leek-orchids-are-beautiful-endangered-and-we-have-no-idea-how-to-grow-them-103224

Australia’s native rhododendrons hide in the high mountain forests

Rhododendron plants have been found on nine peaks and tablelands in the Wet Tropics region of north Queensland. Recent climate modelling research published by scientists from James Cook University and the CSIRO predicts significant reductions in suitable habitat for a suite of mountaintop flora species in Australia’s tropics. The habitat of many of these species is predicted to disappear altogether well before the end of the century. Using rhododendron as a model, the Australian Tropical Herbarium at James Cook University is working to save these threatened species through ‘ex situ’ conservation – cultivation in temperate zone public gardens, well outside their natural range. **https://theconversation.com/australias-native-rhododendrons-hide-in-the-high-mountain-forests-105218**

Spinifex grass would like us to stop putting out bushfires, please

Spinifex grass: it’s spiky, dominates a quarter of the continent, and has no recognised grazing value. To top it all off, people have reportedly experienced anaphylactic shock from being pricked by its sharp leaf tips. It turns out that these less desirable traits are also its virtue. A plethora of birds, mammals and reptiles rely on the unique plant for their survival – to such an extent that it’s considered a keystone of its environment. **https://theconversation.com/spinifex-grass-would-like-us-to-stop-putting-out-bushfires-please-105651**

Native plants put on a colourful show as wildflowers spring to life

Floriade has been and gone but Canberra is about to bloom into colour again this spring. The nation's capital is about to hit peak wildflower season where the natural pinks, yellows and blues of Australia's native flowers come into their own. It's a sight that ecologists and others passionate about Australia's native landscape hope will grow even more colourful with significant work going into conserving Canberra's native grasslands. The ACT government and community organisation Friends of Grasslands this week held a two-day forum that explored the work currently being undertaken in ACT grasslands. **https://www.canberratimes.com.au/national/act/native-plants-put-on-a-colourful-show-as-wildflowers-spring-to-life-20181026-p50c4e.html**

Val Williams Scholarship in Botany 2019

Applications are now invited from scholars undertaking scientific research at the Honours, Masters or PhD levels. The research should contribute to the knowledge, conservation or propagation of Australian native plant species in the Sydney or surrounding regions. The North Shore Group of Australian Plants Society NSW awarded the inaugural $2,000 scholarship in 2009 and since then thirteen scholars have used their scholarship money to augment their research. It has been increased to $3,000 for Round Eleven in 2019. Applications close on 8th March 2019 and the successful applicant will be notified by 5th April 2019. An independent selection committee of three North Shore Group members will have the responsibility of selecting the recipient. Application forms can be downloaded here **https://austplants.com.au/NS-4**

IPPS Rod Tallis Award

The International Plant Propagators Society (IPPS) offers the Rod Tallis Youth Award annually to the most commendable achievement by a person over 18 years of age working or studying in horticulture. The winner will have completed a research project, written an article or series of articles, or developed a new process or product. They will then write up their work in a paper to be presented at the next IPPS conference. The paper will be assessed on issues of clarity, originality and relevance to the industry. Achievements of the applicant to date will also be reviewed. A previous winner will assist the successful applicant in preparing and delivering their paper. The winner will be invited to the Annual Conference (Twin Waters, Sunshine Coast) from 29 May to 1 June 2019, with airfare, accommodation and conference registration paid for, plus one year's membership of the IPPS. Applications close Friday 5 April 2019. Application form available here **http://admin.ipps.org/uploads/Rod_Tallis_Award_MASTER_2019.pdf**

Research round up

COMPILED BY KIRSTIN COWLEY

Centre for Plant Biodiversity Research, Canberra. Email: Kirsten.Cowley@csiro.au

Adams, V.M., Douglas, M.M., Jackson, S.E., Scheepers, K., Kool, J.T. & Setterfield, S.A. (2018). **Conserving biodiversity and indigenous bush tucker: practical application of the strategic foresight framework to invasive alien species management planning.** *Conservation Letters* 11(4): e12441 https://doi.org/10.1111/conl.12441

Addicott, E., Newton, M., Laurance, S., Neldner, J., Laidlaw, M. & Butler, D. (2018). **A new classification of savanna plant communities on the igneous rock lowlands and Tertiary sandy plain landscapes of Cape York Peninsula bioregion.** *Cunninghamia* 18: 29-72. https://doi.org/7751/cunninghamia.2018.18.003

Albers, H.J., Hall, K.M., Lee, K.D., Taleghan, M.A. & Dietterich, T.G. (2018). **The role of restoration and key ecological invasion mechanisms in optimal spatial-dynamic management of invasive species.** *Ecological Economics* 151: 44-54. https://doi.org/10.1016/j.ecolecon.2018.03.031

Armsworth, P.R., Jackson, H.B., Cho, S.H., Clark, M., Fargione, J.E., Iacona, G.D., Kim, T., Larson, E.R., Minney, T. & Sutton, N.A. (2018). **Is conservation right to go big? Protected area size and conservation return-on-investment.** *Biological Conservation* 225: 229-236. https://doi.org/10.1016/j.biocon.2018.07.005

Baruch, Z., Caddy-Retalic, S., Guerin, G.R., Sparrow, B., Leitch, E., Tokmakoff, A. & Lowe, A.J. (2018). **Floristic and structural assessment of Australian rangeland vegetation with standardized plot-based surveys.** *PLoS ONE* https://doi.org/10.1371/journal.pone.0202073

Bradshaw, S.D., Dixon, K.W., Lambers, H., Cross, A.T., Bailey, J. & Hopper, S.D. (2018). **Understanding the long-term impact of prescribed burning in mediterranean-climate biodiversity hotspots, with a focus on south-western Australia.** *International Journal of Wildland Fire* 27: 643-657. https://doi.org/10.1071/WF18067

Burrows, G.E., Alden, R. & Robinson, W.A. (2018). **The lens in focus – lens structure in seeds of 51 Australian *Acacia* species and its implicatsion for imbition and germination.** *Australian Journal of Botany* 66: 398-413. https://doi.org/10.1071/BT17239

Cresswell, I. D. & Murphy, H. T. (2017). **Australia state of the environment 2016: biodiversity, independent report to the Australian Government Minister for the Environment and Energy.** Australian Government Department of the Environment and Energy, Canberra. https://soe.environment.gov.au/sites/g/files/net806/f/soe2016-biodiversity-launch-version2-24feb17.pdf?v=1488792935

Davey, S.M. (2018). **Reporting Australia's forest biodiversity II: threatened forest-dwelling and forest-dependent species.** *Australian Forestry* https://doi.org.10.1080/00049158.2018.1510627

Dillon, R., Monks, L. & Coates, D. (2018). **Establishment success and persistence of threatened plant translocations in south west Western Australia: an experimental approach.** *Australian Journal of Botany* 66: 338-346. https://doi.org/10.1071/BT17187

Dorrough, J., Oliver, I. & Wall, J. (2018). **Consensus when experts disagree: a priority list of invasive alien plant species that reduce ecological restoration success.** *Management of Biological Invasions* 9(3): 329-341. https://doi.org/10.3391/mbi.2018.9.3.15

Fiedler, S., Perring, M.P. & Tietjen, B. (2018). **Integrating trait-based empirical and modeling research to improve ecological restoration.** *Ecology and Evolution* 8: 6369-6380. https://doi.org/10.1002/ece3.4043

Fletcher Jr., R.J., Didham, R.K., Banks-Leite, C., Barlow, J., Ewers, R.M., Rosindell, J., Holt, R.D., Gonzalez, A., Pardini, R., Damschen, E.I., Melo, F.P.L., Ries, L., Prevedello, J.A., Tscharntke, T., Laurance, W.F., Lovejoy, T. & Haddad, N.M. (2018). **Is habitat fragmentation good for biodiversity?** *Biological Conservation* 226: 9-15. https://doi.org/10.1016/j.biocon.2018.07.022

Freudenberger, D. (2018). **Matching effort to threat: strategies to increase the scale and effectiveness of revegetation in southern Australia.** *Ecological Management & Restoration* 19(S1): 6-10. https://doi.org/10.1111/emr.12322

Gibson-Roy, P. (2018). **Restoring grassy ecosystems – feasible or fiction? An inquisitive Australian's experience in the USA.** *Ecological Management & Restoration* 19(S1): 11-25. https://doi.org/10.1111/emr.12327

Gornish, E.S. & Roche, L.M. (2018). **The value of cooperative extension for involving society in restoration and conservation.** *Restoration Ecology* https://doi.org/10.1111/rec.12861

Gosper, C.R., Yates, C.J., Cook, G.D., Harvey, J.M., Liedloff, A.C., McCaw, W.L., Thiele, K.R. & Prober, S.M. (2018). **A conceptual model of vegetation dynamics for the unique obligate-seeder eucalypt woodlands of south-western Australia.** *Austral Ecology* 43: 681-695. https://doi.org/10.1111/aec.12613

Guan, Y., Kang, R. & Liu, J. (2018). **Evolution of the field of ecological restoration over the last three decades: a bibliometric analysis.** *Restoration Ecology* https://doi.org/10.1111/rec.12899

Guerin, G.R., O'Connor, P.J., Sparrow, B. & Lowe, A.J. (2018). **An ecological climate change classification for South Australia.** *Transactions of the Royal Society of South Australia* 142(1): 70-85. https://doi.org/10.1080/03721426.2018.1438803

Hekkala, A.-M. & Roberge, J.-M. (2018). **The use of response measures in meta-analyses of land-use impacts on ecological communities: a review and the way forward.** *Biodiversity and Conservation* 27: 2289-3005. https://doi.org/10.1007/s10531-018-1583-1

Iacona, G.D., Sutherland, W.J., Mappin, B., Adams, V., Armsworth, P.R., Coleshaw, T., Cook, C., Craigie, I., Dicks, L., Fitzsimmons, J.A., McGowan, J., Plumptre, A., Polak, T., Pullin, A., Ringma, J., Rushworth, I., Santangeli, A., Stewart, A., Tulloch, A., Walsh, J. & Possingham, H.P. (2018). **Standardized reporting of the costs of management interventions for biodiversity conservation.** *Conservation Biology* https://doi.org/10.1111/cobi.13195

Kindsvater, H.K. Dulvy, N.K., Horswill, C., Juan-Jordá, M.-J., Mangel, M. & Matthiopoulos, J. (2018). **Overcoming the data crisis in biodiversity conservation.** *Trends in Ecology & Evolution* 33(9): 676-688. https://doi.org/10.1016/j.tree.2018.06.004

Leiper, I., Zander, K.K., Robinson, C.J., Carwadine, J., Moggridge, B.J. & Garnett, S.T. (2018). **Quantifying current and potential contributions of Australian indigenous peoples to threatened species management.** *Conservation Biology.* https://doi.org/10.1111/cobi.13178

Leys, B.A., Marlon, J.R., Umbanhowar, C. & Vanniére, B. (2018). **Global fire history of grassland biomes.** *Ecology and Evolution* 8: 8831-8852. https://doi.org/10.1002/ece3.4394

Lindenmayer, D., Michael, D., Crane, M. & Florance, D. (2018). **Ten lessons in 20 years: insights from monitoring fauna and temperate woodland revegetation.** *Ecological Management & Restoration* 19(S1): 36-43. https://doi.org/10.1111/emr.12303

Makinson, R.O. (2018). **Myrtle Rust reviewed: the impacts of the invasive pathogen *Austropuccinia psidii* on the Australian environment.** Plant Biosecurity Cooperative Research Centre, Canberra. http://www.apbsf.org.au/

Makinson, R.O. (2018). **Myrtle Rust in Australia – a draft Action Plan.** Presented at the Plant Biosecurity Cooperative Research Centre's National Science Exchange, Melbourne, 31 May 2018. Plant Biosecurity Cooperative Research Centre, Canberra, June 2018. http://www.apbsf.org.au/

Maron, M. & Louis, W.R. (2018). **Does it matter why we do restoration? Volunteers, offset markets and the need for full disclosure.** *Ecological Management & Restoration* 19(S1): 73-78. https://doi.org/10.1111/emr.12330

Matzek, V. (2018). **Turning delivery of ecosystem services into a deliverable of ecosystem restoration.** *Restoration Ecology* https://doi.org/10.1111/rec.12872

McDonald, T. & Dixon, K. (2018). **National standards: reasserting the ecological restoration framework in uncertain times.** *Ecological Management & Restoration* 19(S1): 79-89. https://doi.org/10.1111/emr.12317

McGinness, H.M., Arthur, A.D. & Davies, M. (2018). **Flood regimes driving vegetation and bird community transitions in semiarid floodplain woodlands.** *Ecohydrology* 11(5): e1954. https://doi.org/10.1002/eco.1954

Muñoz-Rojas, M., Chilton, A., Liyanage, G.S., Erickson, T.E., Merritt, D.J., Neilan, B.A. & Ooi, M.K.J. (2018). **Effects of indigenous soil cyanobacteria on seed germination and seedling growth of arid species used in restoration.** *Plant and Soil* 429(1-2): 91-100. https://doi.org/10.1007/s11104-018-3607-8

Murray, N.J., Keith, D.A., Simpson, D., Wilshire, J.H. & Lucas, R.M. (2018). **REMAP: an online remote sensing application for land cover classification and monitoring.** *Methods in Ecology and Evolution* 9: 2019-2027. https://doi.org/10.1111/2041-210X.13043

Neve, P., Barney, J.N., Buckley, Y., Cousens, R.D., Graham, S., Jordan, N.R., Lawton-Rauh, A., Liebman, M., Mesgaran, M.B., Schut, M., Shaw, J., Storkey, J., Baraibar, B., Baucom, R.S., Chalak, M., Childs, D.Z., Christensen, S., Eizenberg, H., Fernández-Quintanilla, C., French, K., Harsch, M., Heijting, S., Harrison, L., Loddo, D., Macel, M., Maczey, N., Merotto Jr, A., Mortensen, D., Necajeva, J., Peltzer, D.A., Recasens, J., Renton, M., Riemens, M., Sønderskov, M. & Williams, M. (2018). **Reviewing research priorities in weed ecology, evolution and management: a horizon scan.** *Weed Research* 58(4): 250-258. https://doi.org/10.1111/wre.12304

Nogués-Bravo, D., Rodriguez-Sánchez, F., Orsini, L., de Boer, E., Jansson, R., Morlon, H., Fordham, D.A. & Jackson, S.T. (2018). **Cracking the code of biodiversity responses to past climate change.** *Trends in Ecology & Evolution* 33(1): 765-776. https://doi.org/10.1016/j.tree.2018.07.005

Ondei, S., Brook, B.W. & Buettel, J.C. (2018). **Nature's untold stories: an overview on the availability and type of on-line data on long-term biodiversity monitoring.** *Biodiversity and Conservation* 27: 2971-2987. https://doi.org/10.1007/s10531-018-1582-2

Pegg, G.S., Lee, D.J. & Carnegie, A.J. (2018). **Predicting impact of *Austropuccinia psidii* on populations of broad leaved *Melaleuca* species in Australia.** *Australasian Plant Pathology* 47(4): 421-430. https://doi.org/10.1007/s13313-018-1574-8

Phillips, H.R.P., Halley, J.M., Urbina-Cardona, N. & Purvis, A. (2018). **The effect of fragment area on site-level biodiversity.** *Ecography* 41(7): 1220-1231. https://doi.org/10.1111/ecog.02956

Rael, R.C., D'Andrea, R., Barabás, G. & Ostling, A. (2018). **Emergent niche structuring leads to increased differences from neutrality in species abundance distributions.** *Ecology* 99(7): 1633-1643. https://doi.org/10.1002/ecy.2238

Raimundo, R.L.G., Guimarães Jr., P.R. & Evans, D.M. (2018). **Adaptive networks for restoration ecology.** *Trends in Ecology & Evolution* 33(9): 664-675. https://doi.org/10.1016/j.tree.2018.06.002

Robinson, N.M., Scheele, B.C., Legge, S., Southwell, D.M., Carter, O., Lintermans, M., Radford, J.Q., Skroblin, A., Dickman, C.R., Koleck, J., Wayne, A.F., Kanowski, J., Gillespie, G.R. & Lindenmayer, D.B. (2018). **How to ensure threatened species monitoring leads to threatened species conservation.** *Ecological Management & Restoration* 19(3). https://doi.org/10.1111/emr.12335

Roche, P.K. & Campagne, C.S. (2018). **From ecosystem integrity to ecosystem condition: a continuity of concepts supporting different aspects of ecosystem sustainability.** *Current Opinion in Environmental Sustainability* 29: 63-68. https://doi.org/10.1016/j.cosust.2017.12.009

Rosauer, D.F., Byrne, M., Blom, M.P.K., Coates, D.J., Donnellan, S., Doughty, P., Keogh, J.S., Kinloch, J., Laver, R.J., Myers, C., Oliver, P.M., Potter, S., Rabosky, D.L., Silva, A.C.A., Smith, J. & Moritz, C. (2018). **Real-world conservation planning for evolutionary diversity in the Kimberley, Australia, sidesteps uncertain taxonomy.** *Conservation Letters* 11(4): e12438. https://doi.org/10.1111/conl.12438

Rosetto, M., Bragg, J., Kilian, A., McPherson, H., van der Merwe, M. & Wilson, P.D. (2018). **Restore and renew: a genomics-era framework for species provenance delimitation.** *Restoration Ecology*. https://doi.org/10.1111/rec.12898

Smith, R. & Watson, A. (2018). **Working with nature to improve the environment and profitability of irrigated cotton production at 'Kilmarnock', Namoi Valley, New South Wales.** *Ecological Management & Restoration* 19(S1); 63-72. https://doi.org/10.1111/emr.12321

Soanes, K., Sievers, M., Chee, Y.E., Williams, N.S.G., Bhardwaj, M., Marshall, A.J. & Parris, K.M. (2018). **Correcting common misconceptions to inspire conservation action in urban environments.** *Conservation Biology*. https://doi.org/10.1111/cobi.13193

Thakur, M., Schättin, E.W. & McShea, W.J. (2018**). Globally common, locally rare: revisiting disregarded genetic diversity for conservation planning of widespread species.** *Biodiversity and Conservation* 27(11): 3031-3035. https://doi.org/10.1007/s10531-018-1579-x

Travers, S.K., Dorrough, J., Oliver, I., Somerville, M., Watson, C.J. & McNellie, M.J. (2018). **Using tree hollow data to define large tree size for use in habitat assessment.** *Australian Forestry* 81(3): 186-195. https://doi.org/10.1080/00049158.2018.1502736

Tulloch, A.I.T., Auerbach, N., Avery-Gomm, S., Bayraktarov, E., Butt, N., Dickman, C.R., Ehmke, G., Fisher, D.O., Grantham, H., Holden, M.H., Lavery, T.H., Leseberg, N.P., Nicholls, M., O'Connor, J., Roberson, L., Smyth, A.K., Stone, Z., Tulloch, V., Turak, E., Wardle, G.M. & Watson, J.E.M. (2018). **A decision tree for assessing the risks and benefits of publishing biodiversity data.** *Nature Ecology & Evolution* 2: 1209-1217. https://doi.org/10.1038/s41559-018-0608-1

Ware, C., Williams, K.J., Harding, J., Hawkins, B., Harwood, T., Manion, G., Perkins, G.C. & Ferrier, S. (2018). **Improving biodiversity surrogates for conservation assessment: a test of methods and the value of targeted biological surveys.** *Diversity & Distributions* 24: 1333-1346. https://doi.org/10.1111/ddi.12766

Williams, G. (2018). **Insects associated with flowering of *Rhodomyrtus psidioides* (Myrtaceae): Is this a myrtle rust (*Austropuccinia psidii*)-induced plant-pollinator interaction extinction event?** *Cunninghamia* 18: 23-27. https://doi.org/7751/cunninghamia.2018.002

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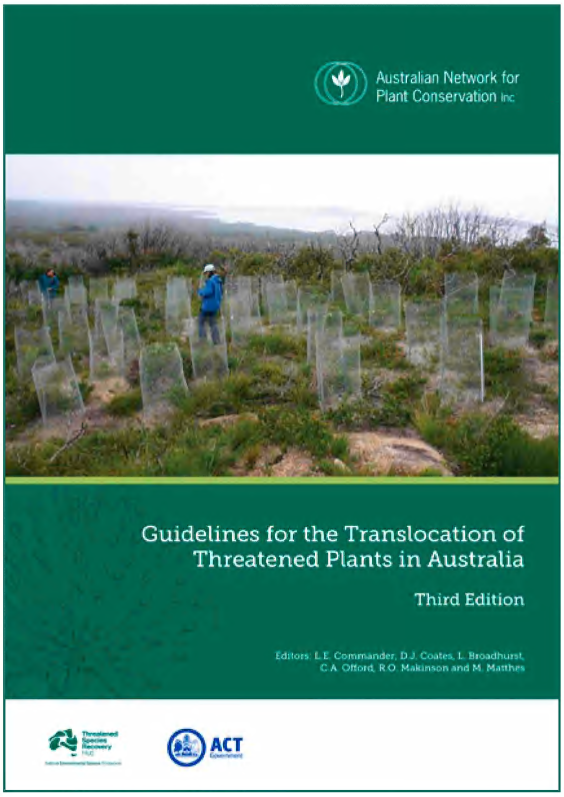
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Guidelines for the Translocation of Threatened Plants in Australia

Third Edition

Editors: L.E. Commander, D.J. Coates, L. Broadhurst, C.A. Offord, R.O. Makinson and M. Matthes

Step-by-step information on how to do best-practice translocations, improve translocation success and contribute to preventing plant extinctions.

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Images: Leonie Monks, Rebecca Dillon and Sarah Barrett collecting seeds from a *Lambertia orbifolia* translocation (Photo: D Coates). *Grevillea wilkinsonii* flowers (Photo: J Briggs). Seedling recruitment of *Brachyscome muelleri* (white flower) being monitored with the assistance of a quadrat. (Photo: M Jusaitis). *Grevillea scapigera* inflorescences (Photo: S Krauss).

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